
METAL PROGRESS
MAY 1958

This John Bean Visubalancer—for checking out-of-balance automobile wheels, uses a TOCCO-hardened main shaft (shown above) to insure long life of wearing surfaces.

with TOCCO* Induction Heating

● If your plant operations include hardening, brazing, soldering or heating for forging of ferrous or non-ferrous metals, savings such as experienced by John Bean Division of Food Machinery and Chemical Corporation can probably be accomplished in your plant, too.

TOCCO is Economical—Cost of hardening this shaft was reduced by $2.00 when TOCCO replaced conventional heat-treating methods. TOCCO also made possible redesign of shaft which reduced its weight 12½ lbs.—a very important additional savings.

TOCCO is Fast—Entire heating and quenching cycles take only seconds, floor to floor time less than a minute. Production is 70 per hour, using 100 KW, 10,000 cycles.

TOCCO Stops Rejects—Distortion is no longer a problem because automatic TOCCO doesn't heat the whole shaft—just those areas which require hardening. Rejects due to variation in heat-treating are eliminated because TOCCO is automatic—produces identical results—on two parts or two million.

TOCCO Engineers—can probably find applications in your plant, too, where TOCCO Induction Heating can increase output and cut unit costs. Such a survey costs you nothing—and may save you a great deal.

THE OHIO CRANKSHAFT COMPANY

JUST PUSH A BUTTON

TOCCO

—Mail Coupon Today—

NEW FREE BULLETIN

THE OHIO CRANKSHAFT CO.
Dept. R-4, Cleveland 1, Ohio

Please send copy of "A TOCCO Plant Survey—Your Profit Possibility for 1950"

Name ____________
Position ____________
Company ____________
Address ____________
City ________ Zone ____ State ________

how MICROCASTINGS SAVE SCRAP AND TOOL BREAKAGE

MICROCAST T. M. REG. U. S. PAT. OFF.

Precision Cast Parts for Tough Jobs

Forward-looking design engineers find that Microcast for small components offers many opportunities for product improvement and substantial savings in cost. This is particularly true where resistance to wear or corrosion is desired with the high-melting-point alloys and where the part is of intricate shape, requiring expensive machining operations under conventional production methods. Perhaps your products present a problem Microcast can tackle?

Write for Free Booklet. More complete information on Microcast is contained in a 16-page booklet published by Austenal Laboratories, Inc., originators of the Microcast Process. This valuable booklet is fully illustrated and describes many applications for Microcasting as well as a step-by-step description of the process itself. Write for your copy today.

MICROCAST

MICROCAST DIVISION
AUSTENAL LABORATORIES, INC.
224 East 39th Street • New York 16, New York
715 East 69th Place • Chicago 37, Illinois

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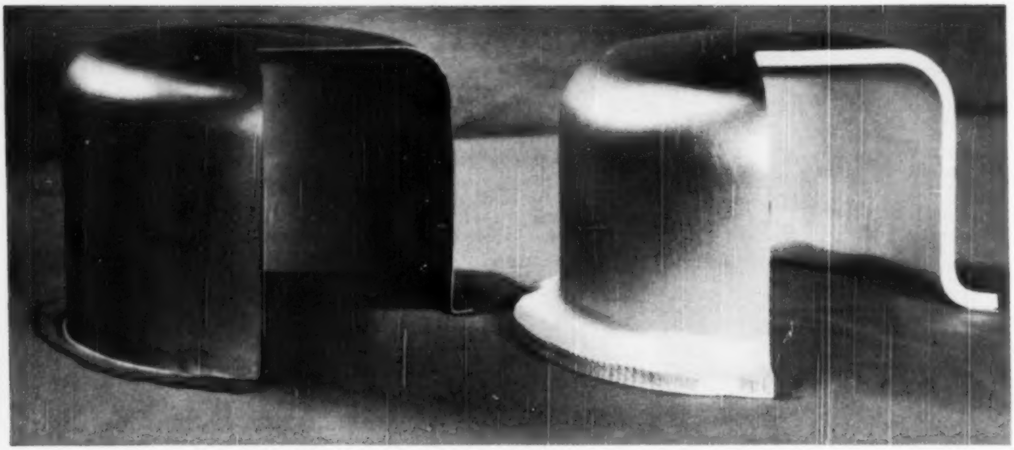

A FEW WELL KNOWN AJAX USERS

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Brown & Sharpe Mfg. Company
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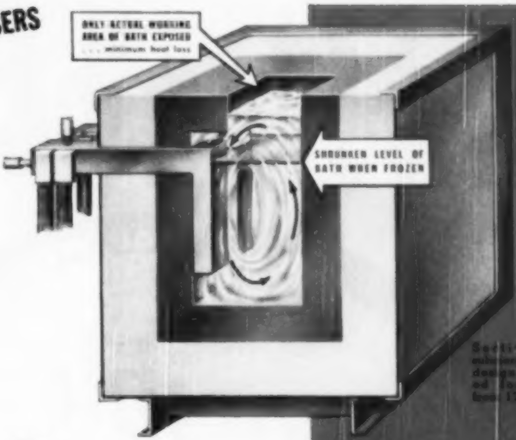
Stanley Works
Thompson Products Company
Threadwell Tap & Die Company
[illegible] Twist Drill Company
[illegible]
[illegible]
[illegible] Electric [illegible]
. . . and dozens of others



Sectional view of submerged electrode design recommended for operations from 1700° to 2400°F.

THE Preferred Practice

FOR HARDENING TOOLS AND DIES

(High Speed, High Carbon-High Chromium, Stainless and Carbon Steels)

When such an imposing array of the world's leading makers of high speed tools and dies adopt the same heat treating method and equipment, you can count on it that there's a reason— several reasons in fact.

Productive capacity is two or three times that of other heat treating methods because of faster heating.

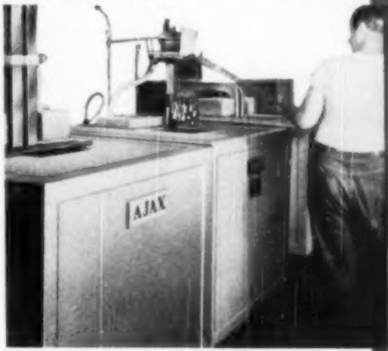
Distortion is negligible.

Surface protection is unsurpassed— because the salt bath seals the work *automatically* from all atmosphere. Scaling, decarb and pitting are avoided.

Temperature control is closer, more accurate. The temperature will not vary more than 5°F. *in any part of the bath.*

The life of tools is increased from 25% to 300% over those heated by ordinary methods.

Adaptability—The Ajax Salt Bath handles any type of high speed, carbon or alloy tool and die steel. Moreover, it occupies less floor space, does not require a skilled operator and provides maximum protection and long life for pots.



Typical installation for hardening high speed tools. Preheat, high heat and quench furnaces. The center unit operating at 2350°F. is equipped with submerged electrodes (see illustration at upper right). Preheat and quench units have suspended electrodes.

Through this unique and patented Ajax submerged electrode design, the efficiency of salt bath hardening is increased in the following ways:

Power Consumption Decreased as Much as 30%—Only the actual working area of bath exposed.

Electrode Life Greatly Extended—Electrodes not exposed to severe oxidizing action at surface of bath.

Bath Rectification Simplified—[illegible] reduced due to restricted bath surface.

Restarting is Easy—Closely-spaced electrodes melt salt from top downward. No danger of sealed-in pressure. No damage to pot or electrodes.

Accurate Temperature Control—[illegible] insures temperature uniformity within 5°F. throughout bath.

Overheating of Work Eliminated—Electrodes, closely-spaced, set against back wall of furnace, prevent heating current from entering work. Entire bath depth available for work.

Salt Leaks Prevented—Com[illegible].

Easier Charging and Discharging—[illegible].

Write for Ajax Bulletin 123

AJAX ELECTRIC COMPANY, INC.
910 Frankford Avenue, Philadelphia 23, Pa.

THE WORLD'S LARGEST MANUFACTURER OF ELECTRIC HEAT TREATING FURNACES EXCLUSIVELY

In Canada: Canadian General Electric Co., Ltd., Toronto, Ont.
Associate Companies: Ajax Metal Co. • Ajax Electric Furnace Corp.
Ajax Electrothermic Corp. • Ajax Engineering Corp.

SELF-HEATING • SELF-CIRCULATING

AJAX ELECTRIC SALT BATH FURNACES

Now! a better way

Here's how it works:

To use the Selector, all you need know is the characteristics that come with the job: type and condition of material to be worked, the number of pieces to be produced, the method of working, and the condition of the equipment to be used.

FOUR STEPS— and you've got the *right* answer!

1. Move arrow to major class covering application
2. Select sub-group which best fits application
3. Note major tool characteristics (under arrow) and other characteristics in cut-outs for each grade in sub-group
4. Select tool steel indicated

That's all there is to it!

Here's an example:

Application—Deep drawing die for steel

Major Class—Metal Forming—Cold

Sub-Group—Special Purpose

Tool Characteristics—Wear Resistance

Tool Steel—Airdi 150

One turn of the dial does it!
And you're sure you're right!!

to select tool steels

Get the right answer instantly

The CRUCIBLE TOOL STEEL SELECTOR uses the only *logical* method to select the *right tool steel right from the start!* Your own experience tells you that the *application* should dictate the choice of the tool steel... and Crucible has applied 50 years of tool steel leadership to adapt this idea to the simplest, handiest instrument you've ever used—the Crucible Tool Steel Selector. Put an end to costly trial and error tool steel selection. When you're tooling up, a turn of the Selector gives you the *right answer*—instantly.

Satisfactory in every case

Now you can start with the application, and the answer you get from the Selector will prove satisfactory in every case, for the Crucible Tool Steel Selector covers 22 Tool Steels which fit 98% of all Tool Steel applications. You no longer need to start with a steel of known characteristics and back your judgment with a costly trial experiment.

And here's an important production point! ALL the tool steels on the Crucible Tool Steel Selector are in warehouse stock . . . that means when you get the answer, you can get the steel . . . fast!

Send for your selector today

You'll want the CRUCIBLE TOOL STEEL SELECTOR . . . and we want you to have it! Remember—nothing you've seen before approaches your tool steel problems so simply and logically!

mail this now

Crucible Steel Company of America
Dept. MP, Chrysler Building
New York 17, N. Y.

Gentlemen:

Sure! I want my CRUCIBLE TOOL STEEL SELECTOR!

Name ______________________ **Title** __________

Company ______________________________

Street ________________________________

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CRUCIBLE first name in special purpose steels

TOOL STEELS

fifty years of Fine steelmaking

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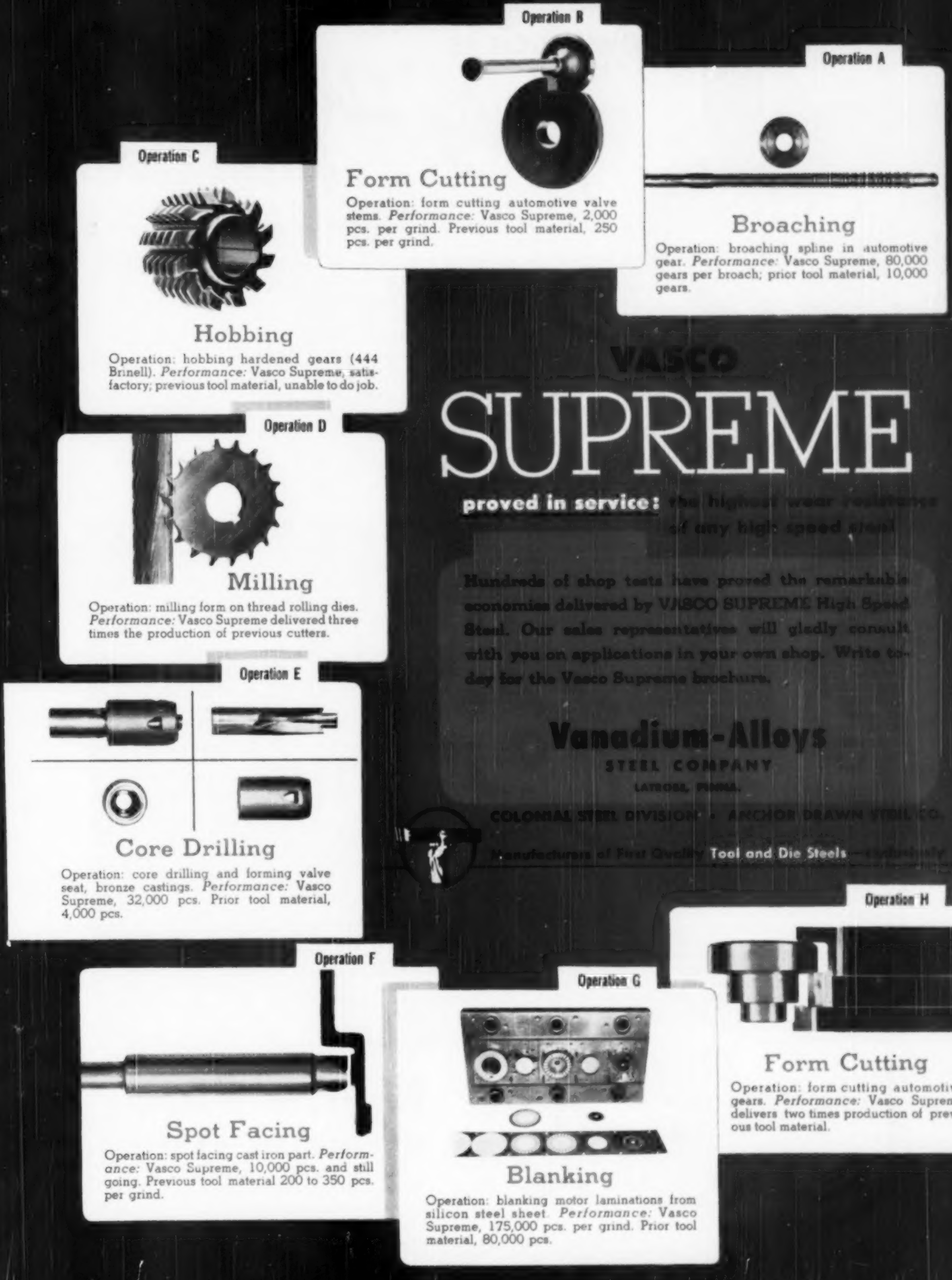
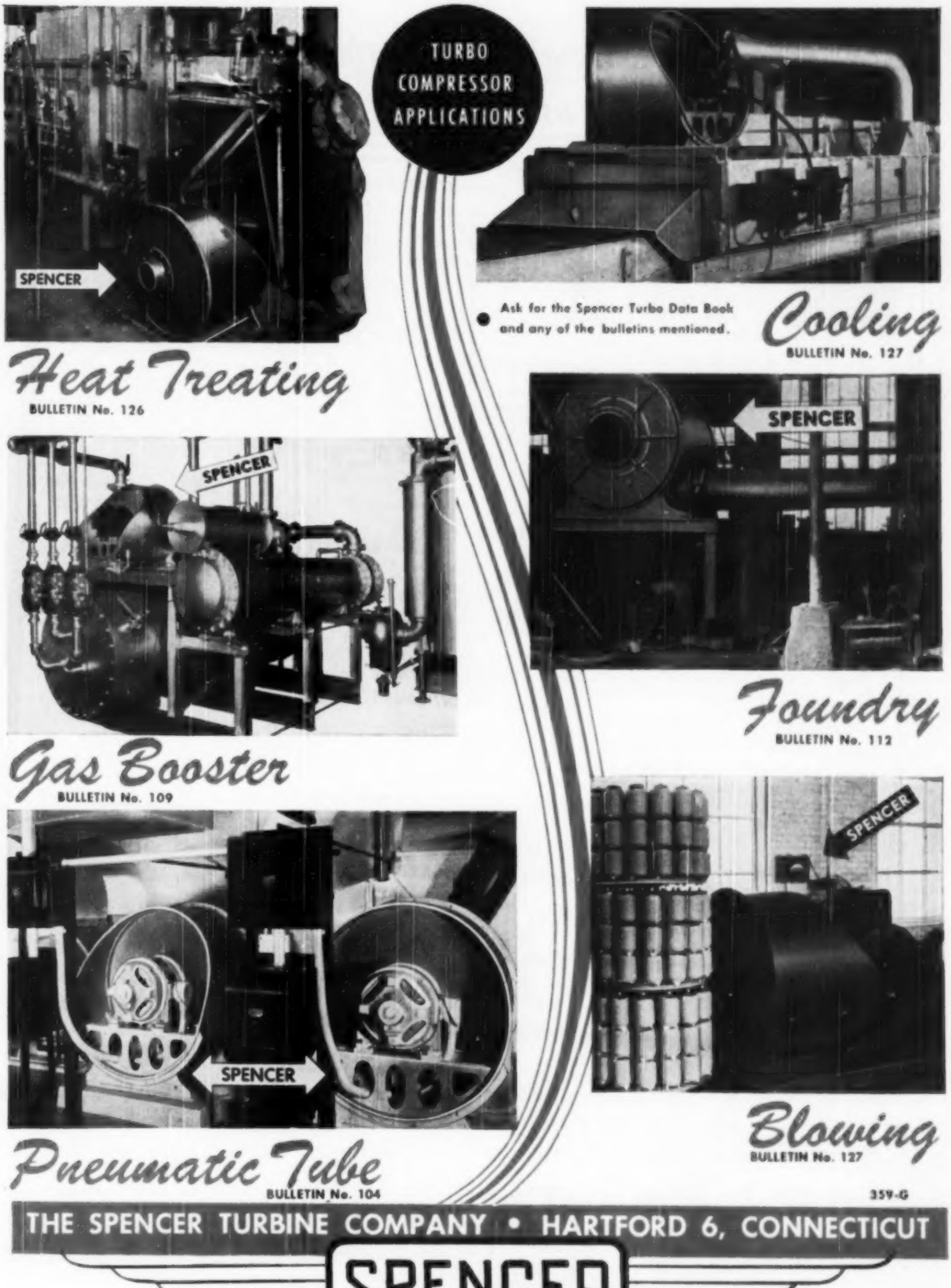

Operation B
Form Cutting
Operation: form cutting automotive valve stems. *Performance:* Vasco Supreme, 2,000 pcs. per grind. Previous tool material, 250 pcs. per grind.
Operation A
Broaching
Operation: broaching spline in automotive gear. *Performance:* Vasco Supreme, 80,000 gears per broach; prior tool material, 10,000 gears.
Operation C
Hobbing
Operation: hobbing hardened gears (444 Brinell). *Performance:* Vasco Supreme, satisfactory; previous tool material, unable to do job.
VASCO
SUPREME
proved in service: the highest wear resistance of any high speed steel
Operation D
Milling
Operation: milling form on thread rolling dies. *Performance:* Vasco Supreme delivered three times the production of previous cutters.
Hundreds of shop tests have proved the remarkable economies delivered by VASCO SUPREME High Speed Steel. Our sales representatives will gladly consult with you on applications in your own shop. Write today for the Vasco Supreme brochure.
Operation E
Core Drilling
Operation: core drilling and forming valve seat, bronze castings. *Performance:* Vasco Supreme, 32,000 pcs. Prior tool material, 4,000 pcs.
Vanadium-Alloys
STEEL COMPANY
LATROBE, PENNA.
COLONIAL STEEL DIVISION • ANCHOR DRAWN STEEL CO.
Manufacturers of First Quality Tool and Die Steels—Exclusively
Operation H
Form Cutting
Operation: form cutting automotive gears. *Performance:* Vasco Supreme delivers two times production of previous tool material.
Operation F
Spot Facing
Operation: spot facing cast iron part. *Performance:* Vasco Supreme, 10,000 pcs. and still going. Previous tool material 200 to 350 pcs. per grind.
Operation G
Blanking
Operation: blanking motor laminations from silicon steel sheet. *Performance:* Vasco Supreme, 175,000 pcs. per grind. Prior tool material, 80,000 pcs.


TURBO COMPRESSOR APPLICATIONS
SPENCER
Heat Treating
BULLETIN No. 126
Ask for the Spencer Turbo Data Book and any of the bulletins mentioned.
Cooling
BULLETIN No. 127
SPENCER
Gas Booster
BULLETIN No. 109
SPENCER
Foundry
BULLETIN No. 112
SPENCER
Pneumatic Tube
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Blowing
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How many of these Accessories are YOU using in your TESTING PROGRAMS?
RECORDERS
For testing machines of all makes, including the new MD-2 type with self contained load recording system. Bulletin 262.
EXTENSOMETERS
For use with recorders. High and low magnification, of many types, also compressometers. Bulletin 262.
GRIPS
Templin Type (illustrated), wedge jaws with replaceable file-face inserts, or universal open front. Bulletin 261-A.
DIAL EXTENSOMETERS
Available for round or flat specimens, in regular or averaging types. Bulletin 263.
FLEXURE TOOLS
For span lengths ½" to 16" for specimens up to 2" width and depth for plastics and other materials. Bulletin 262.
COLD BEND TESTER
Equipped with 13 pins, ⅜" to 3¼" dia. Bends rounds or squares up to 2½". Bulletin 261-A.
AIR CELLS
With Bourdon gage or T.E. indicators, capacities of 2 lbs. to 1200 lbs. full scale. Use with testing machine or any load-applier. Bulletin 262.
COMPRESSION JIG
Prevents buckling of sheet. Accommodates specimens up to .5" thick, ½" x 2½". Bulletin 261-A.
CONTROLLED TEMPERATURE CABINETS
Fits S-T-E standard machines. Controlled temps. between −70° and 200° F. Bulletin 284.
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For high-temperature tensile testing up to 1800° or 2000° F. Bulletin 261-A.
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For S-T-E machines. Holds load within two dial divisions over extended periods. Bulletin 261-A.
PROGRAM CONTROLLER
Automatically controls tests at preselected speeds. Of especial interest for rapid production testing. Bulletin 261-A.
GAGE POINT PUNCH
Centers round or flat specimens—marks centers, with adjustable force on both sides with push or handle. Bulletin 261-A.
REDUCTION OF AREA GAGE
Gives reduction of area of specimen quickly and accurately. Metric dial if desired. Bulletin 261-A.
LOAD CELLS AND INDICATORS
Emery hydraulic cells with Bourdon gage and T-E Indicators. Almost limitless utility. Bulletin 288.
The items shown, merely suggest the many Baldwin accessories that can make your testing machines even more valuable tools of research, development, and product-improvement. Individual bulletins which carry a detailed description of each item are listed by number. Any or all will be sent on request.
The Baldwin Locomotive Works, Philadelphia 42, Pa., U. S. A. Offices: Chicago, Cleveland, Houston, New York, Philadelphia, Pittsburgh, San Francisco, St. Louis, Washington. In Canada: Peacock Bros., Ltd., Montreal, Quebec.
BLW
THE BALDWIN GROUP
BALDWIN
TESTING HEADQUARTERS
5800

Bulletin on SUPER REFRACTORIES by CARBORUNDUM

TRADE MARK

NO. 7 MAY, 1950

Why Are They Called Super Refractories?

Super refractories are so called because their "custom-made" properties permit their use in certain applications where, for various reasons, other refractories may fall short.

The principal constituents of most super refractories are produced in the electric furnace, and for that reason, are sometimes termed "electric furnace refractories." Among these synthetic raw materials are silicon carbide, aluminum oxide and mullite, each of which has unique properties of particular value in a refractory. Silicon carbide for example, is characterized by high thermal conductivity, great hardness, high mechanical strength and resistance to thermal shock. On the other hand, electric furnace mullite has relatively low heat conductivity, high hot strength, chemical stability and excellent resistance to corrosive slags.

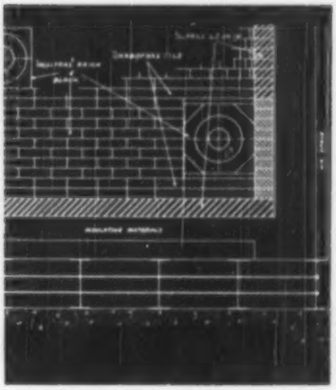
These distinctive properties are retained to the highest degree in the finished super refractory by combining a maximum amount of a specific raw material with specially selected bonds. By varying the constituents to enhance certain characteristics, a variety of each type of super refractory is obtained, each one suitable to some set of unusual service requirements.

Physical Properties of Super Refractories by CARBORUNDUM

Trade Mark

	CARBOFRAX Silicon Carbide	MULLFRAX Electric Furnace Mullite	MULLFRAX S Converted Kyanite	ALFRAX K Electrically Fused Alumina	ALFRAX B	ALFRAX BI
Heat Conductivity at 2200° F. in BTU/hr. sq. ft. and °F./in. of thickness	109 BTU	16 BTU	9 BTU	24 BTU	12 BTU	7 BTU
REFRACTORINESS PCE CONE	37-40	38-39	37-38	37-39	39-40	38-39
SPALLING RESISTANCE	High	High	High	Good	Good	Good
ABRASION RESISTANCE	High	Medium	Medium	High	Medium	Low
THERMAL EXPANSION (25° — 1400° C.)	.0000044	.0000059	.0000049	.0000074	.0000086	.0000086
MODULUS OF RUPTURE @ 2460° F. PSI	800-3125	100-250	175-475	100-1050	100-225	50-100
WEIGHT 9 IN. STRAIGHT	9.25 lbs.	9 lbs.	8 lbs.	10.1 lbs.	7.25 lbs.	4.8 lbs.

Why 3 Different Super Refractories Are Used



To obtain balanced, efficient operation in this air pre-heater, three different super refractories are employed in zones where the unique properties of each are best fitted to deliver the greatest possible benefit.

MULLFRAX electric furnace mullite brick line the combustion zone. Here their extremely high refractoriness and chemical stability assure long periods of trouble-free service in this critical high temperature location.

CARBOFRAX silicon carbide tile span the burner flues. Their high strength and resistance to heat shock keep repairs to this section of the setting at a minimum.

ALFRAX BI electrically fused alumina brick are used in the upper section of the furnace. Their low heat capacity and high refractoriness provide efficient, low cost operation.

As a result of this balanced combination of *super refractory* characteristics, overall operating cost is low.

Super Refractory Slag Hole Blocks Assure Continuous Runs

Through the use of CARBOFRAX silicon carbide slag hole blocks in continuous-pour cupolas, expensive delays for slag hole replacement during a run are eliminated. These dense, durable blocks resist slag erosion — original hole size is maintained even through runs of 18-20 hrs. There is practically no enlargement even when the blast is on. Also aiding satisfactory performance is the high resistance of these super refractory blocks to spalling, cracking and elevated temperatures.

Address all correspondence to: Dept. C-50, THE CARBORUNDUM COMPANY, Refractories Division, Perth Amboy, New Jersey

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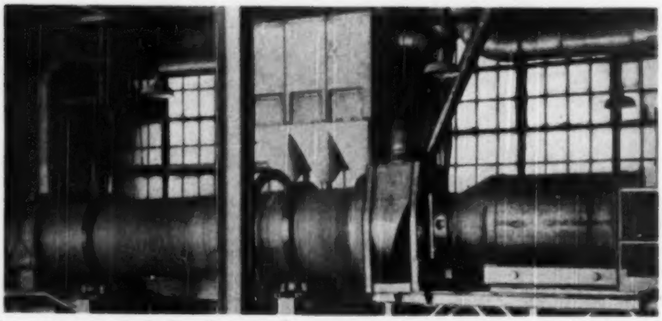
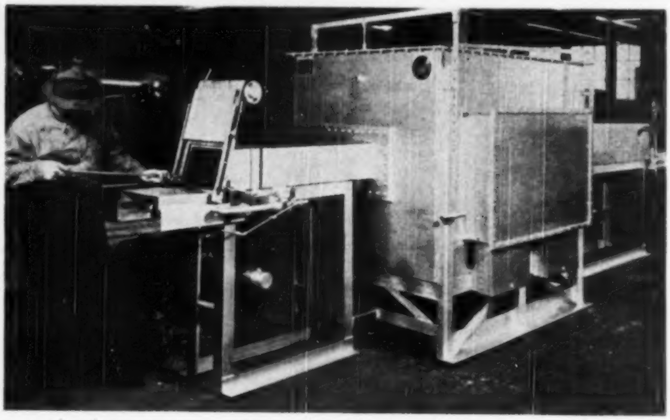
How Unique Properties of Super Refractory Paid Off



Until ALFRAX B electrically fused alumina brick were used to line the combustion chamber of this rotary type abrasive grain dryer, the extremely high temperatures developed quickly broke down the other lining materials. Repairs and/or replacements were required on an average of once a month. However, after installing ALFRAX B brick, service life was extended to two years.

This super refractory material successfully withstands extremely high temperatures, resists flame erosion, and has a comparatively low heat conductivity. As a result greater output is obtained, labor costs are way down and considerable savings on replacement materials are effected. Such benefits are typical when super refractories are correctly applied to special applications like this one.

Extra Efficiency Realized With Super Refractories



The unique properties of super refractories are used to excellent advantage in this Harper electric furnace to obtain improved furnace performance at lower fuel and repair costs. The CARBOFRAX silicon carbide hearth, installed in the hot zone of this continuous sintering and brazing unit, offers high thermal conductivity, resistance to abrasion and high refractoriness. Heat is transmitted rapidly and uniformly to the work and the furnace can be operated with a lower heat head thereby relieving the severity of conditions imposed on other refractories. The service life of the hearth is extended, fuel consumption lowered and repairs and replacements cut.

ALFRAX K electrically fused alumina piers, supporting the hearth, successfully resist the softening effects of high temperatures — help maintain a flat, level floor at all times. The hearth, at either end of the hot zone, is constructed of MULLFRAX S converted kyanite tile because of their low heat conductivity, good resistance to spalling, cracking and abrasion. This combination of properties, — found only in super refractories — helps reduce replacement costs still further while eliminating furnace outages for repairs.

A Better Product Finish Because of Super Refractories ▶

The finish on stainless steel sheets produced in this annealing furnace was improved materially as the direct result of installing a CARBOFRAX silicon carbide muffle. The atmosphere required for this better finish is readily maintained. There is less oxide or scale formation on the sheets. The cold rolled finish is retained. A considerable reduction in pickling time is realized.

One of the principal properties of the CARBOFRAX material that makes its use so desirable in this type of application is its high heat conductivity. The sheets are quickly and evenly heated. Temperature control is steady and accurate. Fuel consumption shows practically no increase (as compared with open firing) while fuel combustion is more efficient. Also, a long muffle life is assured because CARBOFRAX tile are very resistant to high temperatures, cracking and spalling.

The improved bright finish provided by the CARBOFRAX muffle is protected from scratching and marring during annealing through the use of specially designed CARBOFRAX skid rails. These rails resist heat shock and high temperatures while their high thermal conductivity reduces the possibility of non-uniform heating of the sheets.

This combination of benefits was made possible only by the use of *super refractories.*

To obtain facts and figures on installations in specific fields merely select from this list of bulletins. Copies will be sent you at once. No obligation, of course.

- Super Refractories by CARBORUNDUM (general catalog)
- Super Refractories for the Ceramic Industry
- Super Refractories for the Process Industry
- Super Refractories for Boiler Furnaces
- Super Refractories for Heat Treatment Furnaces
- Super Refractories for Gas Generators
- The Frax Line of Cements
- CARBOFRAX Refractory Skid Rails
- Porous Media for Filtration & Diffusion

Dept. No. C-50

THE CARBORUNDUM COMPANY

Refractories Division

PERTH AMBOY, NEW JERSEY

HERE IS AN OUTSTANDING FAMILY of insulating fire brick for back-up or exposed use . . . the only family of its kind . . . that gives you a complete range . . . a *quick heating* insulating fire brick for every purpose.

By taking advantage of the quick heating characteristics of these insulating fire brick, you'll benefit through important savings in fuel because of the quicker rise to proper operating temperature in the furnace. This is a result of the low heat storage capacity and low thermal conductivity characteristics of the brick. These factors are especially important where furnaces are being intermittently operated.

The same materials can also be obtained in large size units as Johns-Manville Insulating Fireblok. This product has many advantages over the smaller size fire brick, from both a construction and stability standpoint. They can be quickly applied because they are easy to cut and fit. J-M Insulating Fireblok provide additional heat savings because they reduce the number of joints, and require less mortar for bonding.

Why not have a Johns-Manville insulation expert call to tell you more about ways in which you can save by using these insulations in your furnaces. Write Johns-Manville, Box 290, New York 16, N. Y. for further information.

	JM-1620	JM-20	JM-23	JM-26	JM-28	JM-3000
Densities, lb per cu ft	29	35	42	48	58	63-67
Transverse Strengths, psi	60	80	120	125	120	200
Cold Crushing Strengths, psi	70	115	170	190	150	400
Linear Shrinkage,† percent	0.0 at 2000 F	0.0 at 2000 F	0.3 at 2300 F	1.0 at 2600 F	4.0 at 2800 F	0.8 at 3000 F
Reversible Thermal Expansion, percent	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F
Conductivity* at Mean Temperatures						
500 F	0.77	0.97	1.51	1.92	2.00	3.10
1000 F	1.02	1.22	1.91	2.22	2.50	3.20
1500 F	1.27	1.47	2.31	2.52	3.00	3.35
2000 F	—	1.72	2.70	2.82	3.50	3.60
Recommended Service						
Back up	2000 F	2000 F	2300 F	2600 F	2800 F	3000 F
Exposed	1600 F	2000 F	2300 F	2600 F	2800 F	3000 F

† 24-hr simulative service panel test for JM-3000; 24-hr soaking period for other brick.

* Conductivity is expressed in Btu in. per sq ft per F per hour at the designated mean temperatures.

Note: Above tests are in accordance with A.S.T.M. tentative standards.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville First in INSULATIONS

Now... Yoloy Pipe

CONTINUOUS WELD

for use where corrosion is a problem

FOR fifteen years, Yoloy steel has been manufactured as Seamless pipe, sheets, plates and structural members. Yoloy is used in the oil, mining, railroad, chemical, trucking and other industries where resistance to corrosion and abrasion are a problem and lighter weight construction is important. Now this same unique nickel-copper low-alloy steel is available as continuous weld pipe.

Yoloy continuous weld pipe has these outstanding characteristics:

1. It is easy to weld,
2. It bends and fabricates readily,
3. Its tensile strength is high,
4. It is resistant to abrasion,
5. Its resistance to shock and vibration is high,
6. It is high in corrosion resistance.

Yoloy has an atmospheric corrosion resistance from four to six times that of regular carbon steels. Its resistance to many other corrosive elements likewise is high, making Yoloy pipe particularly well adapted for use in the railroad, oil, mining and chemical process industries. Youngstown Yoloy continuous weld pipe also affords distinct advantages for use where piping is concealed in industrial plants, commercial buildings and residences.

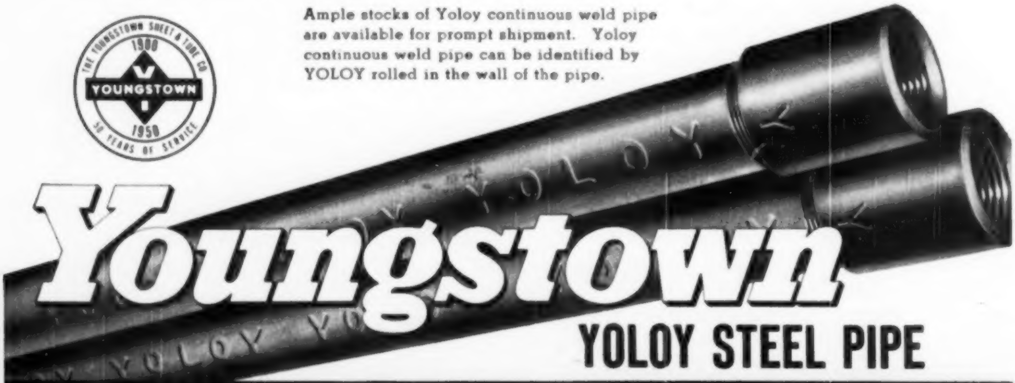
For example, at a sewage plant, Yoloy pipe immersed in the sour sludge of a digester was found to be in good condition after nearly four years. When repairs were made to replace a mild steel tripod holding the pipe after only one year's service, it was found that the tripod had been almost entirely eaten up by the acid sludge.

Yoloy continuous weld pipe installed in brine lines from the wells at a salt plant is still in service after several years. Pipe previously used in this same line had to be replaced 3 or 4 times a year.

Other examples of the unusual service given by Yoloy pipe can be cited. For further information, write or phone the Youngstown District Sales Office nearest you.

THE YOUNGSTOWN SHEET & TUBE CO. 1900 YOUNGSTOWN 1950 50 YEARS OF SERVICE

Ample stocks of Yoloy continuous weld pipe are available for prompt shipment. Yoloy continuous weld pipe can be identified by YOLOY rolled in the wall of the pipe.



Youngstown

YOLOY STEEL PIPE

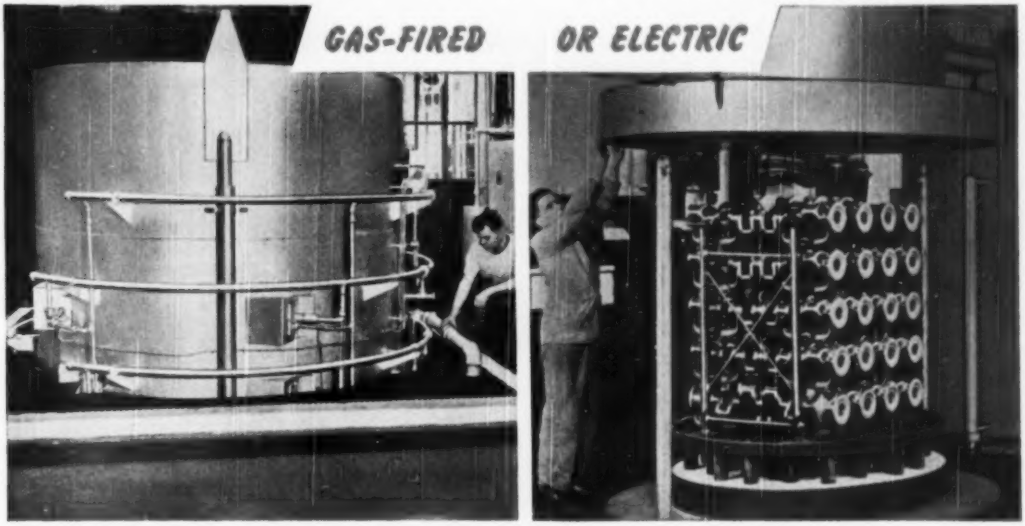
THE YOUNGSTOWN SHEET AND TUBE COMPANY General Offices — Youngstown 1, Ohio

Manufacturers of Carbon, Alloy and Yoloy Steel Export Office - 500 Fifth Avenue, New York

PIPE AND TUBULAR PRODUCTS - CONDUIT - BARS - RODS - COLD FINISHED CARBON AND ALLOY BARS
SHEETS - PLATES - WIRE - ELECTROLYTIC TIN PLATE - COKE TIN PLATE - RAILROAD TRACK SPIKES

YOU CAN BE **SURE**.. IF IT'S

Westinghouse



FOR THE MAN WHO CAN'T BE "SOLD"

Careful buyer? Then, here is help in selecting the equipment to do your job best. You see, Westinghouse makes both electric and gas-fired furnaces, plus the atmosphere equipment that may be required. Thus, Westinghouse engineers have no favorite type of firing or construction to sell. Instead, they study your heat-treating problems with a view toward recommending the equipment to do your job best.

And you can preview results! A well-equipped metallurgical laboratory will sample heat-treat your work and demonstrate the mass production results you may expect.

This unbiased engineering and metallurgical service is called Therm-a-neering. It matches the equipment to your job . . . provides the hundreds of design details that make your heat-treat line run smoothly and economically.

Give Therm-a-neering a chance to help you. You won't have to be sold. You'll know why it's best to buy Westinghouse. Call your nearby Westinghouse representative for details, or write Westinghouse Electric Corporation, 180 Mercer Street, Meadville, Pa.

J-10346

Therm-a-neering. **A HEAT AND METALLURGICAL SERVICE THAT OFFERS WITHOUT OBLIGATION:**

ENGINEERS—Thermal, design and metallurgical engineers to help you study your heat-treating problems with a view toward recommending specific heat-treating furnaces and atmospheres.

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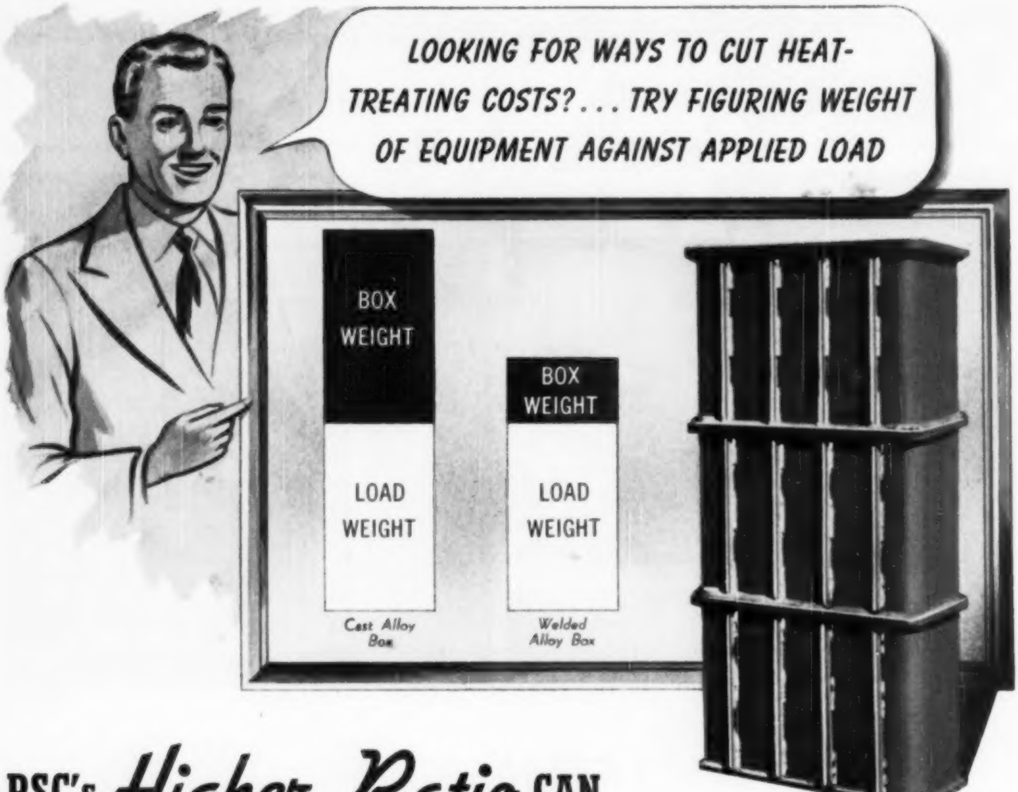
PRODUCTION—A modern plant devoted entirely to industrial heating.

EXPERIENCE—Manufacturers of a wide variety of furnaces—both gas and electric—and protective atmosphere generators.

Westinghouse
GAS AND ELECTRIC
Furnaces



PSC's *Higher Ratio* CAN LOWER YOUR COSTS 3 WAYS

In many installations the above PSC annealing boxes have tripled the weight ratio of load and box. For example, in one recent installation the cast boxes which were replaced weighed as much as the 300-lb. load; a ratio of 1:1. The PSC sheet-welded boxes, carrying the same load, weighed 2/3 less; ratio 3:1. A study made by one customer showed that, due to this higher ratio, the saving in fuel needed to heat the metal itself of the old boxes was $40 a furnace cycle. Another installation showed that the saving in heat-up and handling time shortened the cycle as much as 5 hours. Let us show you how PSC light-weight, welded alloy equipment can save you fuel, as well as handling and treating time.

Light-Weight Heat-Treating Equipment for Every Purpose

- Carburizing and Annealing Boxes
- Baskets - Trays - Fixtures
- Muffles - Retorts - Racks
- Annealing Covers and Tubes
- Pickling Equipment
- Tumbling Barrels - Tanks
- Cyanide and Lead Pots
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- Heat, Corrosion Resistant Tubing

We furnish standard or special welded alloy equipment in any size, and in any metal to meet your heat and corrosion requirements. Send blue prints or write as to your needs.

THE PRESSED STEEL COMPANY
of WILKES-BARRE, PENNSYLVANIA

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

☆ ☆ ☆ OFFICES IN PRINCIPAL CITIES ☆ ☆ ☆

Our customer's original orders called for a number of Nichrome muffles—each over 50 feet long—for use at temperatures approximating 1800° F.

To obtain such exceptionally long muffles, Driver-Harris engineers proposed that cast Nichrome sections be welded together—forming integral units in the lengths required.

Since Driver-Harris had had long and successful experience with large weldments of this type, the user was assured he would obtain service life approximating that of one-piece castings. With such assurance, and because the units were urgently needed for *one of the most important industrial undertakings in the country,* the customer agreed to the cast-and-weld method of construction.

Ever since their installation several years ago, these giant muffles have given complete satisfaction, and their dependable performance has led to a repeat order: Three more muffles, identical with those initially produced . . . except for an increase in length to 67 feet.

We can offer no better testimony to the efficiency and reliability of our welding procedures than this.

Versatile Nichrome is available in cast, rod, sheet, strip and wire forms—enabling us to handle complete production of heat-treating equipment of the most desirable design.

And other than Nichrome, we can furnish D-H cast alloys such as Chromax* and Cimet*. You'll find these unsurpassed in conventional furnace applications, outstanding when required to meet unusually severe conditions. So send us your specifications. We'll gladly make recommendations based upon your specific needs.

FIFTIETH ANNIVERSARY
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D/H
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Nichrome and Chromax castings
are manufactured only by

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HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco

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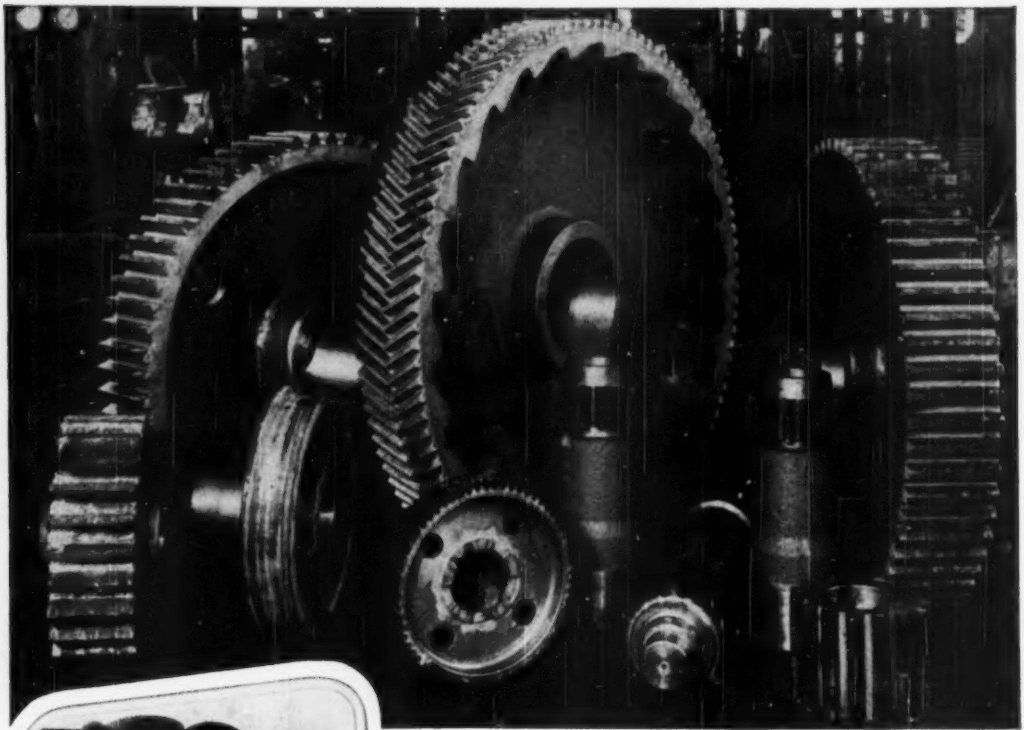

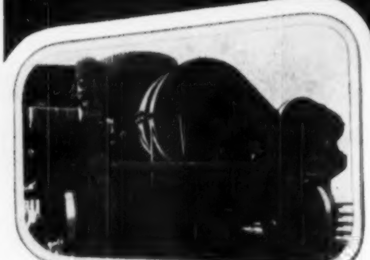

(NE)

CRANE GEARS and TRACK WHEELS have *Greater Internal Stress Value . . .*

HERE IS WHY

FOR COMPARATIVE PURPOSES

we tabulate below the physical properties of the surface and core values of SAE-1020, SAE-2315, Steels, Carburized or Case Hardened with "NELOY" and "NELOY-MOLY" Steels Normalized or Liquid Quenched, Finish Machined and Flame Hardened.

	Ultimate Tensile Lbs. per Sq. In.	Elastic Limit or Yield Point Lbs. per Sq. In.	Elongation Percent	Reduction of Area Percent	Brinell	Scleroscope
S.A.E. 1020 Case Hardened (Surface)	260/300,000	180/195,000	5-10	8-12	514-601	71-81
S.A.E. 1020 Case Hardened (Core)	60/ 70,000	30/ 35,000	30-35	40-50	120-140	17-20
Neloy Annealed and Flame Hardened Treatment 10B (Surface)	218/270,000	190/240,000	8-12	20-35	477-590	66-80
Neloy Annealed and Flame Hardened Treatment 10B (Core)	85/ 90,000	58/ 65,000	23-40	30-40	163-170	23-24
S.A.E. 1020 Case Hardened (Surface)	260/300,000	180/195,000	5-10	8-12	514-601	71-81
S.A.E. 1020 Case Hardened (Core)	60/ 70,000	30/ 35,000	30-35	40-50	120-140	17-20
Neloy Heat-treatments No. 3 and 10B (Surface)	220/270,000	200/240,000	8-12	20-35	550-590	68-80
Neloy Heat-treatments No. 3 and 10B (Core)	100/110,000	80/ 90,000	20-26	40-50	202-240	29-33
S.A.E. 2315 Case Hardened (Surface)	290/329,000	185/205,000	4- 8	6-10	570-653	78-87
S.A.E. 2315 Case Hardened (Core)	112/129,000	99/120,000	12-20	38-51	249-275	35-39
Neloy-Molybdenum, Normalized, Drawn and Flame Hardened (Surface)	258/281,000	212/217,000	6-10	8-12	514-555	71-75
Neloy-Molybdenum, Normalized, Drawn and Flame Hardened (Core)	90/110,000*	65/ 85,000*	18-25	30-40	190-220	28-33
S.A.E. 2315 Case Hardened (Surface)	290/329,000	185/205,000	4- 8	6-10	570-653	78-87
S.A.E. 2315 Case Hardened (Core)	112/129,000	99/120,000	12-20	38-51	249-275	35-39
Neloy-Molybdenum Heat-treatments 3A and 10B Flame Hardened (Surface)	282/318,000	217/265,000	4- 8	6-10	555-627	75-84
Neloy-Molybdenum Heat-treatments 3A and 10B Flame Hardened (Core)	132/150,000	120/135,000	10-18	25-35	290-320	41-45

*The variation in tensile and yield in the third table is due to the alloyed elements of 2315 which is a nickel steel. This produces a higher physical on a straight annealed steel compared with more economical alloy used in Neloy Moly.

NATIONAL ERIE CORPORATION

ERIE, PENNSYLVANIA • U. S. A.

This High Vacuum Furnace...

may mean far longer life for Gas Turbines

Designed and built by National Research, this new high vacuum furnace will be used to explore new properties of molybdenum . . . may well hold the answer to the need for a tougher, more heat resistant material for gas turbines. Now at Battelle Memorial Institute, it was developed for the Navy Bureau of Ordnance under the technical direction of the Applied Physics Laboratory of the John Hopkins University.

This is but one more example of how high vacuum equipment is being used to solve research and commercial metallurgy problems . . . to produce purer, stronger, *better metals.* If you have a problem in heat treating, sintering, degassing, bright soldering, metal distillation, brazing, thermal reduction, melting or casting . . . high vacuum may hold the answer.

As *the pioneers* in high vacuum work, we have unparalleled experience to help you with your research . . . to design and build the laboratory or commercial equipment you need. Why not write *today!*

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An outstanding development for stripping defective electroplated nickel, copper, silver, cadmium and zinc from steel. Fast action . . . no basis metal attack. The highly polished grill cover illustrated has been completely stripped of nickelplate, and is ready for replating without repolishing.
EBONOL BLACKENING PROCESSES
Ebonol finishes are used to beautify a widely diversified list of superior quality products. Photo shows steel parts blackened with Ebonol-S and S-30; copper and brass with Ebonol-C; zinc with Ebonol-Z. U. S. Patents — 2,364,993, 2,460,896, 2,460,898.
EMULSION CLEANER — 75
Oils, greases, buffing compounds, solid particles, deep seated in steel parts are cleaned out and completely removed by this emulsification process. Stubborn, gummy substances on die castings, milling machines, floors, motor blocks emulsify and disperse in water instantly.
ENAMEL STRIPPERS
Enthone has over 20 strippers for removing organic finishes — synthetic enamels, lacquers, vinyls, japans. The best strippers, tailor-made for your particular problem, are selected by laboratory technicians after test runs. This service is rendered free of charge.

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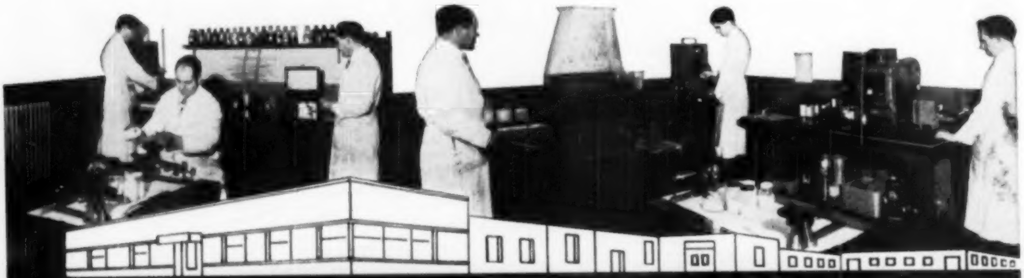
"fluid-film" . . . the all-purpose die lubricant for light or heavy stampings — the latest thing in semi-plastic emulsions — is a non-pigmented compound with great film strength.

- *Brush it — dip it — roll it — spray it*
- *Draw with it (wet or dry)*
- *Dilute it (within limits)*
- *Weld through it*
- *Anneal it*
- *Clean it*

"fluid-film" is low priced, easy to apply and easier to clean, making it the real buy in the die lubricant field. We're sure this is what you have been looking for.



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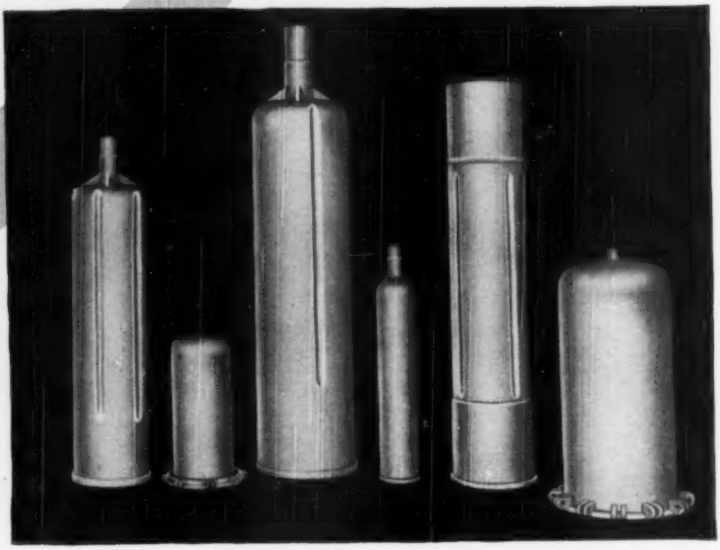
The St. Joseph Lead Company's electrothermic smelter at Josephtown, Pa.

The plant operates as a custom smelter, receiving both domestic and foreign concentrates. Constructed in 1930, it was designed to process 3,600 tons per month of zinc concentrate obtained mainly from the Company's zinc mines in St. Lawrence County, N. Y. Expansion of the plant and equipment during 1939 and 1940 brought the processing capacity to about 9,000 tons of concentrate per month. As a result of a postwar expansion program completed in 1950, at a cost of about $8 million, the smelter's processing capacity has increased to 16,000 tons. The following grades of electrothermic zinc are produced: HIGH GRADE • INTERMEDIATE • BRASS SPECIAL • PRIME WESTERN

ST. JOSEPH LEAD COMPANY

250 PARK AVENUE, NEW YORK 17, NEW YORK, ELdorado 5-3200

How long should a Retort last?



3600 hrs.?... 80,000 hrs.?

Let's be honest. We could claim that our retorts last 80,000 hours. Some have. We could claim they last 10,000 or 12,000 hours. Many have.

We have also had some go out of service after 3600 hours. But even so, Thermalloy* had outlasted—for that particular service—most previously used retorts.

The point is, there are too many variables in methods of operation and maintenance for us or any other manufacturer to make general claims on retort life. These factors include: cycle of heating (batch or continuous) . . . method of heating (radiant or direct-fired) . . . frequency of charging . . . operative temperatures . . . type of suspension or support . . . efficiency of maintenance.

This we can say! In *comparable* service, Thermalloy retorts and muffles have attained an outstanding record for "more operating hours per dollar."

For recommendations on your particular installation, contact your nearest Electro-Alloys office, or write Electro-Alloys Division, 1976 Taylor Street, Elyria, Ohio.

*Reg. U. S. Pat. Off.

Specify CHEMALLOY* for corrosion resistance . . . THERMALLOY* for heat and abrasion resistance

Write for Technical Booklet—Cast 16% Cr.—35% Ni Alloys

AMERICAN **Brake Shoe** COMPANY

ELECTRO-ALLOYS DIVISION

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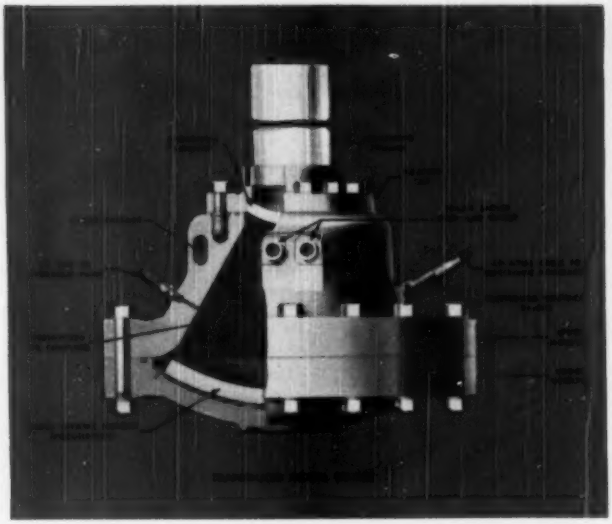


Cutaway view of the Hypersonic Transducer manufactured by The Brush Development Company which finds industry-wide application for emulsification, vaporization, homogenization and degassing of various liquids and solids.

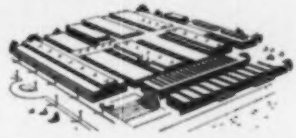
Typical of the tough ones cast by ALCOA

Would you torture your product with a test like this? Brush Development tests the castings we make for their Hypersonic Transducer by filling them with oil under 1,000 pounds pressure—then gives them the quivers at 125,000 vibrations per second. Yet not a trace of oil seeps through.

Whether you're after pressure tightness—or faster machining—or lighter weight—or lower finishing costs—specify Alcoa Castings. The larger the run—the tougher the job—the more Alcoa's modern foundries can save you. No others match our 62 years of aluminum experience. Few equal our production facilities.

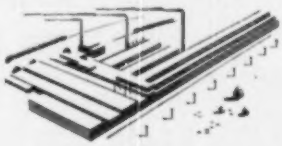
Look for Aluminum Company of America listed in your phone book under "Aluminum". Call there for a casting specialist, or write ALUMINUM COMPANY OF AMERICA, 1993E Gulf Building, Pittsburgh 19, Penna.

CLEVELAND, OHIO



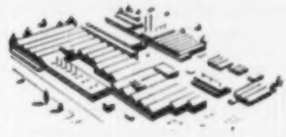
Sand & Permanent Mold Foundries

DETROIT, MICHIGAN



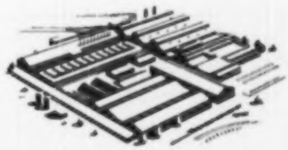
Permanent Mold Foundry

BRIDGEPORT, CONN.



Sand & Permanent Mold Foundries

LOS ANGELES, CALIF.



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ALCOA

ALUMINUM CASTINGS *by* ALCOA

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Division, Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

Extra-Low-Carbon STAINLESS STEEL

New Type Chromium-Nickel Steels Have Added Corrosion Resistance

New and improved austenitic stainless steels of the 18-8 type have been developed which have superior corrosion resistance after being exposed to heat. These steels, known as extra-low-carbon stainless steels, were designed especially for use in welded and stress-relieved equipment that is exposed to more severe corrosive conditions than are normally encountered by other types of straight 18-8 stainless steel.

Under severe corrosive conditions, intergranular attack may occur in the higher carbon unstabilized grades of austenitic stainless steels that have been subjected to the temperature range of 800 to 1600 deg. F. during welding or hot forming operations. It is generally agreed that this type of corrosion is caused by complex carbides that are formed at the grain boundaries of the stainless steel during heating.

The effect of heat is rarely harmful in the ordinary fabrication of stainless steel for most applications, such as in architecture, the food and dairy industries, in hospitals, and in the home. However, in the chemical and other allied industries, where stainless steel is used in the handling of very corrosive chemicals, these new extra-low-carbon stainless steels should most certainly find wide use.

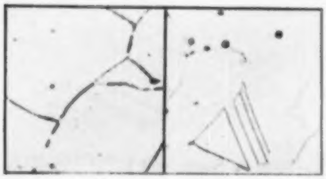


Fig. 1 Left: Carbide precipitation at the grain boundaries of an 18-8 stainless steel, containing 0.059 per cent carbon, after being held at 1200 deg. F. for 1 hour. Right: Absence of carbide precipitation in 18-8 stainless steel of 0.03 maximum carbon content, after being held at 1200 deg. F. for the same length of time.

In general, there are three ways in which the precipitation of carbides can be controlled in stainless steel:

1. Heat-treating so that the carbides present are dissolved.
2. Alloying with an element, such as columbium or titanium, that will tie up the carbon in the form of a harmless carbide.
3. Decreasing the carbon content of the steel.

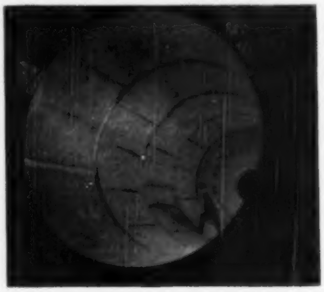


Fig. 2. The new extra-low-carbon stainless steels are especially suited for large types of process equipment, such as this fractionating tower. They require no heat-treatment after welding.

Heat-Treatment After Welding

Before the development of extra-low-carbon stainless steel, or of the "stabilized grades", one means for preventing intergranular corrosion was to heat-treat stainless steel that had been subjected to the dangerous temperature range, so that the precipitated chromium-carbides would go back into solid solution. It was found that when a welded part was heated to temperatures of 1950 to 2000 deg. F., and then cooled rapidly, most of the carbides were retained in solid solution. This extra heat-treatment is sometimes impractical, however, because of the design or massive size of some types of welded equipment.

Use of Columbium and Titanium to "Fix" Carbon

As the result of a search for a method of producing stainless steels that would be immune to intergranular corrosion without heat-treatment, the columbium- and titanium-bearing stainless steels were developed. These elements form carbides more readily than chromium. It was found that columbium, when present in a 10 to 1 ratio to carbon, completely "fixes" the carbon and renders it harmless in stainless steel. A similar effect can be accomplished by alloying with about five times as much titanium as carbon. Steels thus alloyed with columbium or titanium are known as "stabilized grades."

Decreasing Carbon Content

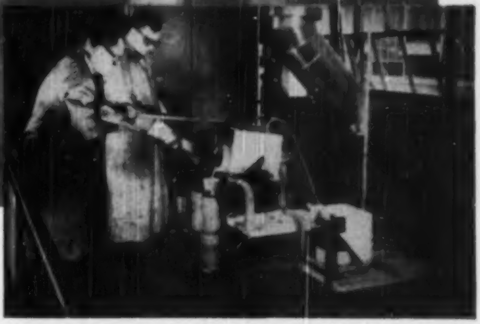
The most recent development in preventing intergranular corrosion has been the extra-low-carbon stainless steels. To be substantially harmless in stainless steel for as-welded or welded and stress relieved chemical equipment operating at temperatures under 700 deg. F., carbon must not be present in quantities over 0.03 per cent.

In 1937, ferrochrome with 0.03 per cent maximum carbon was first produced for the steel industry by ELECTROMET. This product has made it possible to produce very-low-carbon stainless steels—steels that are completely immune to intergranular corrosion when welded or subjected to a stress-relieving heat-treatment.

Metallurgical Service Available

If you use welded stainless steel equipment, it will pay you to investigate the advantages of using extra-low-carbon steels. If you produce stainless steel, our metallurgists will be glad to give you technical assistance in the use of ferrochrome of 0.03 per cent maximum carbon. For further information, write to the nearest ELECTROMET office.

For a more detailed account of the properties of extra-low-carbon stainless steel, write for a free copy of the technical paper, "Resistance to Sensitization of Austenitic Chromium-Nickel Steels of 0.03% Max. Carbon Content".



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"Once you get the technique worked out," says one engineer who has used high-frequency melting for years, "even the toughest melting problems are reduced to routine with Ajax-Northrup's close control."

Yes, the same clean, fast induction melting principle that makes small Ajax-Northrup furnaces ideal for metallurgical research, governs the 300-lb. or the 8-ton production furnace. Fast, oxidation-free melting with no carbon contamination—perfect temperature control at all times—high efficiency and preferential power rates. If you too want laboratory precision in your production melting—at speeds you need—and costs you can afford — send for more information today.

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A glance at the above figures—taken from an actual production run—will reveal the amazing production increases which are possible when ordinary screw steel is replaced with LA-LED—the *fastest machining steel you can buy.*

LA-LED is an entirely *NEW* steel, unlike anything produced before. It has a unique composition which allows startling machining speeds. However, it offers much more. Being an open-hearth steel, it has a much sounder cross section than Bessemer. Its good ductility and surface quality permit bending, crimping, and riveting operations impracticable with Bessemer steels. And, LA-LED machines to a fine satiny finish and provides closer tolerances. LA-LED is available cold-finished—in rounds 5/16" through 3"; in hexagons 5/16" through 1½".

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Manufacturers of the Most Complete Line of Carbon and Alloy Cold-Finished and Ground and Polished Bars in America

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LaSalle Steel Co.
1424 150th Street, Hammond, Indiana
Please give me more information on how LA-LED can increase production and cut the cost of screw machine parts in my shop.

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Title ____________
Company ____________
Address ____________
City ____________ State ____________

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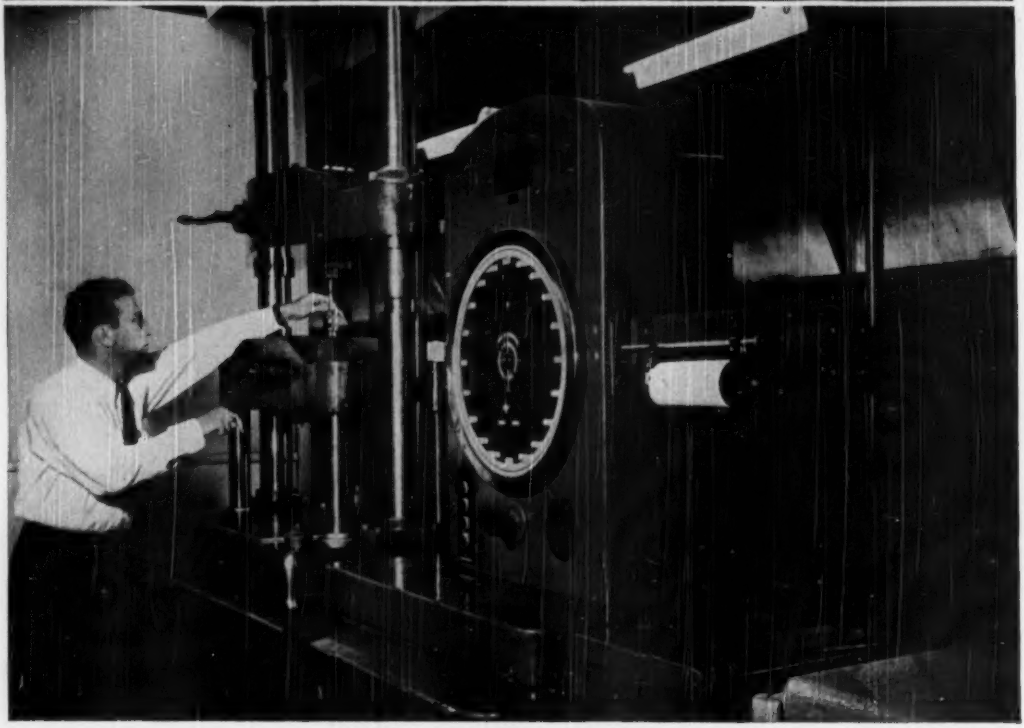

Olsen Electro-Mechanical Universal Testing Machine equipped with Electronic High Magnification Recorder. U. S. Navy, Point Loma, California. OFFICIAL PHOTOGRAPH U.S. NAVY

Extreme accuracy, performance dependability and simplicity of operation combine in the Olsen Electro-Mechanical Universal Testing Machine to give authoritative laboratory and production tests. Equipped with the Olsen Electronic High Magnification Recorder precise stress-strain curves can be plotted successfully.

The Pendulever Weighing System of the Olsen Universal, by its complete freedom from complicated operation, assures low maintenance costs while giving the highest standards of tests.

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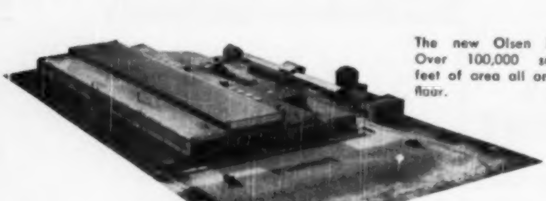

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LINDBERG FURNACES

Editorial Summary of May Metal Progress

IRON ORE REDUCTION PROCESSES

• If some inventor tries to get you interested in a new process for direct reduction of iron ore, compare its heat requirements to Swedish sponge iron (8,200,000 Btu. per ton), the blast furnace (11,000,000 Btu.) and the ancient Catalan forge (100,000,000 Btu.) No wonder the forge is obsolete.......p. 631.

DIGGING UP THE DATA

• All frustrated users of the Tiotots system of filing ("throw it on top of the stack") will bless the metallurgical classification arranged by the ⊕ and the Special Libraries Assoc. and the punch card for needling out the reference, *presto*.......p. 613.

PRECISION GEARS

• Automotive and precision gears are usually quenched in a press to avoid distortion. This is costly in labor. Time quenching in hot oil ("martempering") is now a satisfactory automatic substitute......p. 607.

RESTRICTED METAL

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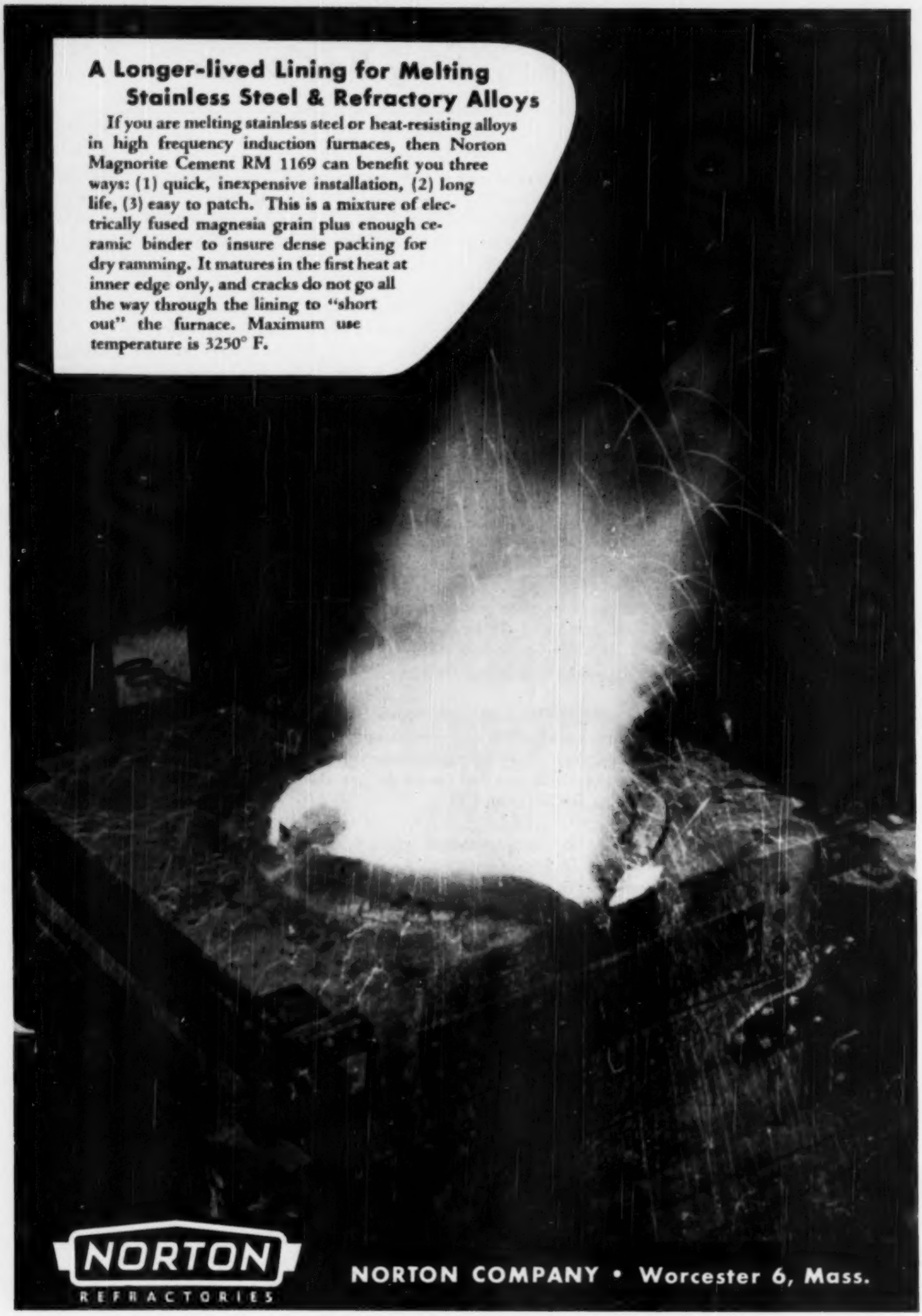
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Metal Progress

The Magazine of Metallurgical Engineering

May 1950
Vol. 57, No. 5

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Cover

Glenn M. Shaw, who teaches advertising art at the Cleveland School of Art, thought that block letters on stainless steel would make an excellent front cover. Photographing a smooth surface, properly highlighted, almost stymied the project until Republic Steel Corp. kindly furnished him with samples of all the commercial finishes. Finally a good negative was shot.

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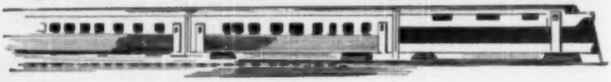

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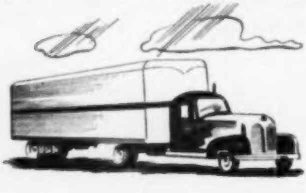

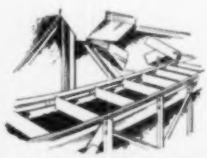

COMPARISON OF AVERAGE PROPERTIES OF HI-STEEL WITH ORDINARY STRUCTURAL GRADE CARBON STEEL

Tensile Properties (¼" Plate)	Inland HI-STEEL	Ordinary Structural Grade Carbon Steel
Yield Point (psi)	56,000	35,000
Ultimate Strength (psi)	73,000	66,000
Elong. in 8" (%)	25	25
Endurance Limit		
Fatigue Strength (psi)	49,000	33,000
Impact Resistance (Charpy Impact—ft. lbs.) Temperature		
80° F	55	36
32° F	43	33
0° F	36	26
—25° F	34	6
—50° F	30	2

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Martempering of Automotive Gears and Shafts

By S. L. Widrig
Chief Metallurgical Engineer
and Wilson T. Groves
Metallurgical Engineer
Spicer Mfg. Division of Dana Corp.
Toledo, Ohio

Martempering (quenching in a hot bath, and then air cooling) is usually regarded primarily as a means of improving the toughness of the hardened parts, since it helps avoid microscopic cracking when the hardening reactions change the specific volume of the various regions at different times and different rates. The authors, however, find that it also avoids distortion so satisfactorily that automotive gears, of carburized low-alloy steel, ordinarily press or plug quenched, can be martempered successfully in production in 350° F. oil.

IN OUR ARTICLE on "Quenching of Carburized Gears" in last month's *Metal Progress*, it was pointed out that distortion could be controlled by quenching over a plug or in a press fixture, but that this was costly in equipment and labor. Alternatively, certain parts (carburized rear axle pinions were cited specifically) have been satisfactorily quenched and held to close dimensional tolerances by automatic equipment in an open tank of cool oil.

For some years we have been considering and experimenting with "martempering" of such important parts in hot oil, and a modified martempering process has now been used on a production basis at Spicer continuously for the past two years. The parts treated are primarily carburized gears and shafts for heavy-duty automotive transmissions and are made from 8620 and 4320 steel. Most of the gears were formerly plug or press quenched and the hot bath quenching process has vastly increased the productivity of the carburizing furnaces with which it is used, and has also resulted in a substantial saving in labor, since one of the furnace operators can be transferred to other work.

The utilization of hot bath quenching to reduce the distortion of steel parts has been a natural consequence of increased knowledge of the mechanism of austenite's decomposition as a function of steel composition, time and temperature. Many valuable contributions to the literature concerning this subject have been made since the studies of isothermal transformation (1930) by Davenport and Bain led to the publication of "S-curves" or "TTT-curves" mapping the relationships between transformation, time and temperature for individual steels.

As is well known, these studies showed that it takes a certain time for the austenite transformation to start, or incubate, at subcritical temperatures, and (in general) the effect of alloys is to lengthen this incubation time. They also showed that the shortest incubation time is usually around 900° F., and if the alloy steel can be quenched past that temperature rapidly enough to, say, 600° F., no transformation starts for a considerable time. Specifically, if a 4340 steel is quenched in a salt bath at 600° F., the austenite does not start to transform until about 40 sec. has elapsed and then requires 20 min. to complete its transformation. At any previous time, if the steel is removed from the 600° bath, the remaining austenite transforms to hard martensite almost completely and very

rapidly as the part cools to room temperature. It has also been shown that true martensite does not start to form until a definite temperature is reached, depending on the composition (but always considerably below 900° F.); austenite transforms in this intermediate range into bainite, a structure of somewhat deficient hardness.

These general principles are the basis of "martempering", an old process defined and put under metallurgical control in this country by B. F. Shepherd, past president of the American Society for Metals. It consists of quenching steel from the austenitizing temperature to a point just above the temperature at which martensite starts to form, commonly called the M_s point, holding long enough to equalize the temperature throughout the piece (or as near as possible), then air cooling. In the hot quenching bath the thermal gradient from surface to center of the steel section is reduced while the steel is in a relatively soft and plastic condition and warpage due to differential thermal stresses is greatly reduced. Subsequently the inevitable volume changes accompanying martensite formation occur uniformly throughout the part while it is cooling comparatively slowly to room temperature, thus minimizing residual stresses. Since it has been reasonably well proven that the martensite transformation at temperatures below M_s is independent of time and occurs only as the temperature drops, no hardness is sacrificed in the finished part, providing its cooling rate from the austenitizing temperature to the M_s point is sufficiently rapid to prevent the formation of high-temperature transformation products — that is, exceeds the critical cooling rate past the "nose" of the S-curve at about 900° F., as mentioned above.

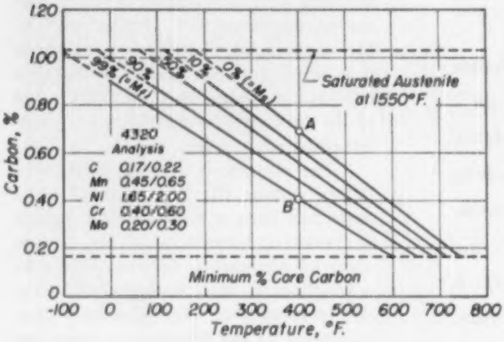


Fig. 6 — Relationships Between Temperature, Carbon Content and Amount of Austenite Transformed to Martensite in Carburized 4320

The M_s point in steel is determined primarily by carbon content and, to a lesser extent, by alloying elements. Figures 6 and 7* have been computed from composition according to *Metal Progress* Data Sheet, page 676-B, October 1946, and indicate the per cent of martensite that may be formed at various temperatures in the case and core of three common carburizing steels, namely, 4320, 4620 and 8620. These curves will give some idea of the actual temperatures that must be utilized in the martempering of the gears and other parts made by us of these steels.

Due to the low initial carbon content of the steels mentioned above, it is impractical to equalize the temperature of a carburized part in a bath maintained above the M_s point of the core (725 to 750° F., according to Fig. 6 and 7). If the part were quenched in a bath at that temperature, the cooling rate past the "nose" of the S-curve (900° F. ±) would be insufficient to prevent considerable transformation of the austenite ("give proper core solution", in shop terms) except in very light sections.

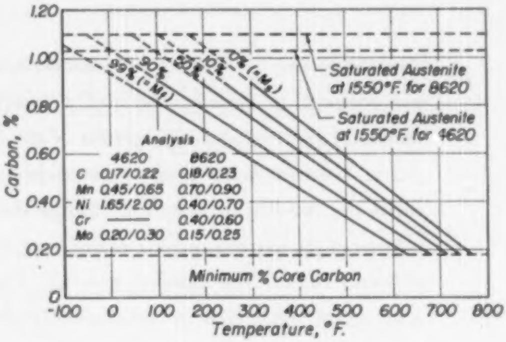


Fig. 7 — Relationships Between Temperature, Carbon Content and Amount of Austenite Transformed to Martensite in Carburized 4620 and 8620 Steels

Fortunately, however, it has been found that most of the distortion occurring in regular oil quenching can be eliminated by a modified martempering process where the quenching and equalizing bath is maintained *within* the temperature range of martensite formation.

A temperature commonly employed is 400° F. Figure 6 for 4320 steel indicates that in the outer portions of the carburized case, where the carbon content is higher than 0.70% (point *A*), no martensite would be formed in the quenching bath.

*Figures are numbered consecutively with the previous article.

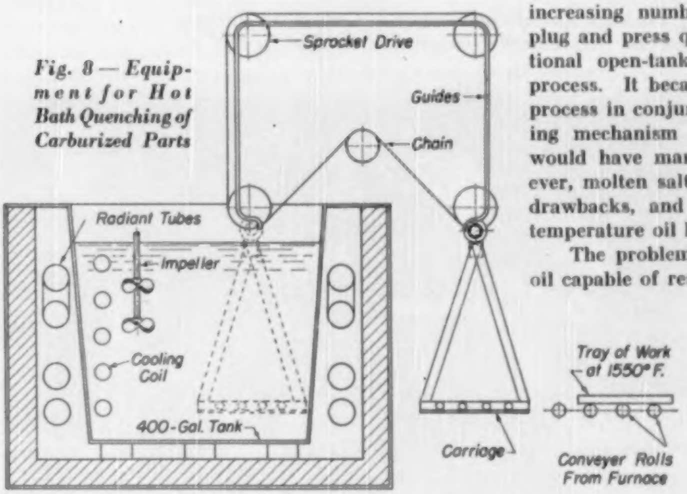
All of the core and the portions of the case having less than 0.40% carbon (point *B*) should be entirely transformed within a minute or less in the quenching bath, while the portions of the case having a carbon concentration between 0.40 and 0.70% should be partially transformed without delay — it being remembered that the austenite → martensite reaction takes a vanishingly small time.

Production Equipment

The equipment illustrated in Fig. 8, currently used for martempering the work from one of the carburizing furnaces, was designed and built at Spicer for experimental purposes.

The tray of hot work is discharged from the furnace vestibule and moved manually over conveyer rolls onto a carriage. The operator then presses a pushbutton to start the automatic quench cycle. The carriage rides into the quench on overhead guides and is actuated by a chain and sprocket drive at either side; the work is about 1550° F. when it enters the bath. At the end of a predetermined immersion time, the drive reverses and the carriage is lifted from the bath and stops over the bath for another predetermined time for draining before returning to its original position, thus completing the cycle. Exposed time between furnace vestibule and quench is short enough so that no serious decarburization results — the work is file hard after quenching. The immersion time and drain time are automatically controlled by suitable timers and electrical relays. After final cooling in air, the work is removed from the furnace tray and deposited manually on hooks suspended from a trolley conveyer which carries it through a washer and the 340° draw unit.

Fig. 8 — Equipment for Hot Bath Quenching of Carburized Parts



Properties of the Oil

A.P.I. gravity	28.3
Flash point	515° F.
Fire point	590° F.
Viscosity at 100° F.	1152*
Viscosity at 210° F.	96*
Viscosity index	96
Neutrality point	0.03

*Saybolt Universal

The tank and auxiliary equipment were originally designed for operation with a molten salt bath maintained at 400° F. Temperature is automatically maintained with pyrometers controlling fuel and air supply valves on the four radiant heating tubes, as well as the air supply to the bank of cooling tubes. Suitable agitation is furnished by two mixers or impellers, one at either end of the tank, inclined 45° toward the tank bottom and located off-center so as not to oppose each other. The double-bladed shaft of each mixer is driven by a ¾-hp. motor.

The above described process gave very satisfactory results and was eagerly adopted by the production department as a means of obtaining quiet running gears of proper dimensions. An increasing number of parts were changed from plug and press quenching (and also from conventional open-tank quenching) to the hot quench process. It became apparent that the use of this process in conjunction with the automatic quenching mechanism described in the former article would have many production advantages. However, molten salt in such a mechanism had some drawbacks, and it was decided to use a high-temperature oil bath, if this could be done.

The problem of securing a moderately priced oil capable of resisting oxidation when maintained between 350 and 400° F. and used to quench heavy loads of work at 1550° F. can well be appreciated by those who have tried it. It is of course also necessary that the oil have satisfactory cooling power and be easily removed from the quenched work in the washing operation preceding the draw. Although many lubricating oils contain additives for inhibiting oxidation at the lower temperatures encountered in internal combustion engines, they are not necessarily effective in the 350 to 400° F. range and they may also be hard to wash off.

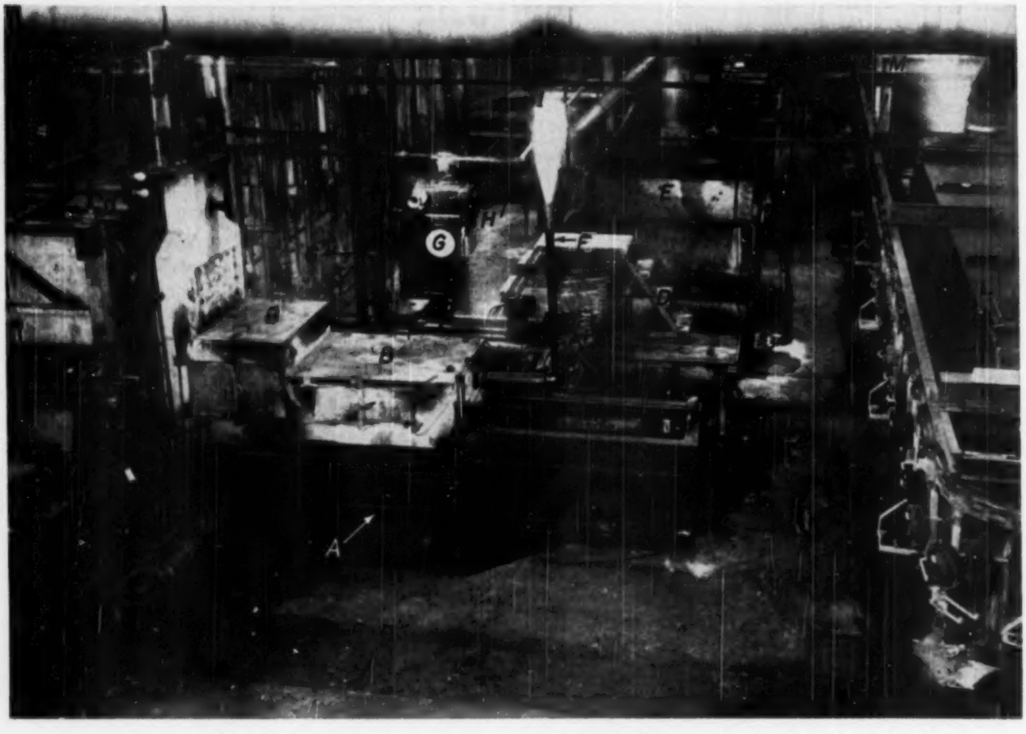
Several recommended oils were tested for oxidation resistance in the laboratory and the two giving the best results were tried at different times in production. The oil finally selected was one containing no oxidation inhibitors and having the properties noted at the side of Fig. 8.

Several additions were made to the equipment shown in Fig. 8, including a centrifuge and an earth-type filter, operating on a bypass from the centrifuge, to remove continuously any soot or oxidation products from the oil bath. The bath temperature was also dropped to 350° F. to lengthen the useful life of the oil. Due to the greater amount of work now quenched in the hot oil and the lower bath temperature, a heat exchanger was installed for additional cooling capacity.

The normal cycle of the carburizing furnace gives each tray 8 min. In order to quench successive trays in hot oil, it was necessary to immerse somewhat less than this to allow for tray transfer and drainage. It was found that 6 min. in the hot oil was sufficient to cool the surface of a bar 3 in. in diameter and 6 in. long to within a few degrees of the bath temperature. Since the surface temperature of the bar did not rise after removal from the oil bath, it was concluded that the temperature was nearly equalized throughout the section and 6-min. immersion was adopted for all parts.

It should be pointed out that the conditions existing for this installation are not ideal for maximum oil life inasmuch as the volume of oil is small for the amount of work quenched (approximately 650 lb. per hr., gross). Also the quench bath is not enclosed and the surface of the bath burns for several seconds after the work is immersed. However, it has served satisfactorily for developing the process on a production basis. The results, dimensionally and metallurgically,

Fig. 9 — View of Discharge End of Continuous Gas Carburizing Furnace From Which Gears Are Automatically Quenched in Oil Bath at 350° F.



Legend

A—Oil tank (below floor level)
B—Enclosed quench chamber extending below oil level
C—Center post of rotating and lowering platform
D—Trays of quenched gears
E—Tray washer
F—Atmosphere outlet from quench chamber
G—Temperature control equipment for oil bath
H—Earth-type oil filter
I—Loaded trays at charge end of furnace
K—Hard conveyer line carrying work through wash and draw units
L—Spray-type washer
M—Recirculating-type draw furnace

have warranted the purchase of electrical heating elements, oil temperature control instruments, filter and mixers for converting the large quench tank shown in Fig. 5 of the article last month (p. 485) to the hot oil process. Figure 9 shows the revised installation, now also used for the martempering of production parts.

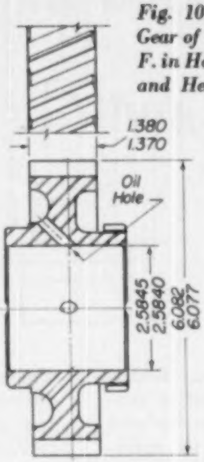


Fig. 10 — 31-Tooth, Round Bore, Mainshaft Gear of Carburized 4320, Quenched From 1550° F. in Hot Oil at 350° F., Then Drawn at 340° F., and Held to Tooth Taper of 0.003 In. Max.

Results on Sliding Gear

An example of the results that can be obtained by hot oil quenching is illustrated by the round-bore mainshaft gear shown in Fig. 10. Prior to the adoption of the hot bath quench, it was necessary to quench this gear on a press to minimize "tooth taper" (the difference in gear diameter from one end of the gear tooth to the other, as measured over specified size balls inserted between the teeth). An attempt was once made to harden this gear by quenching it edgewise in regular oil tank at 130° F. on the automatic lowerator described in the previous article. The results for ten gears quenched in this manner are listed (right), along with the results obtained for ten similar gears quenched edgewise in 350° F. oil with the mechanism shown in Fig. 8. (All 20 gears after quenching were drawn at 340° F.) The maximum allowable taper of this gear is 0.003 in. and all ten of those quenched in 130° F. oil were rejected. All ten gears quenched in 350° F. oil were within the specified limits. Processing was accordingly changed from press quench to hot oil quench for these carburized gears.

Tooth Tapers

Gear No.	Oil at 130°	Oil at 350°
1	0.005 in.	0.001 in.
2	0.006	0.002
3	0.005	0.001
4	0.007	0.003
5	0.004	0.001
6	0.006	0.001
7	0.005	0.002
8	0.006	0.001
9	0.005	0.001
10	0.005	0.001
Allowable	0.003 in.	0.003 in.

Close fits are required on gears for automotive transmissions; it is seldom commercially possible to hold the spline dimensions within specified limits during hot oil quenching. We are therefore currently developing an alternative process consisting of a hot oil quench followed by a finish honing operation. Naturally, it is desirable to hold the dimensions of the part as close as possible during heat treating to facilitate honing and minimize wear on the stones. It can be reasonably expected that such a process will eliminate the wobble that has been found even in many of our best plug quenched gears.

Hardness and Penetration

Numerous tests were made to determine the hardness obtainable in various sized sections after quenching in hot oil. All the gears which were formerly plug quenched were (as a basis of comparison) hardened in still oil maintained at approximately 130° F. Duplicates were then quenched in an agitated high-temperature oil at 350° F. The hot oil quenching was done in the tank shown in Fig. 8.

Table I gives hardnesses so obtained in the teeth of identical gears of both 4320 and 8620 steel carburized simultaneously to 0.050-in. case depth. This particular gear has a 6.283-in. outside diameter, a 1-in. wide tooth face, and weighs 7 lb. The hardness readings across the case were taken at the pitch line of a tooth cross section with a Vickers hardness tester and 5-kg. load, and were then converted to Rockwell C-scale. The lower surface hardness of the 4320 gear quenched in 350° F. oil is attributed to the slightly greater amount of retained austenite in the former (estimated microscopically as 5 to 10% near the working surface).

Table I — Surface Hardness and Penetration in Carburized Gears
All gears drawn at 340° F. after quenching

Location on Pitch Line	Gear of 4320		Gear of 8620	
	Quenched to 130° F.	Quenched to 350° F.	Quenched to 130° F.	Quenched to 350° F.
Surface	61.5	60	61.5	62
0.010 in.	60	60	60.5	60
0.020 in.	60	60	60.5	60.5
0.030 in.	57.5	57	58	58
0.040 in.	53.5	52.5	54	55
0.050 in.	50	48.5	45.5	47
Core	45.5	45.5	45.5	44
Core at root diameter	44.5	42	44.5	42

To determine the hardness obtainable in various sized shafts, four step-down bars of 4320 and 8620 steel (Fig. 11) were simultaneously carburized to 0.050-in. case depth and quenched from 1550° F. in oil at 130 and 350° F. as above described. Disks were then cut from the middle of each size section and hardness traverse readings on radii across each quadrant were taken and averaged.

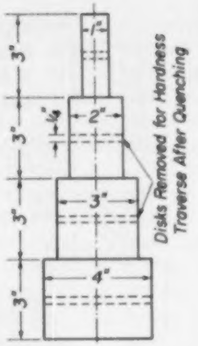


Fig. 11 — Step-Down Bar, Carburized and Hardened by Standard Methods, Used to Determine Hardness Penetration of Alternative Quenching Processes

These hardnesses are not necessarily the same as would be obtained in a long bar of uniform diameter. This is particularly true for the 4-in. section of Fig. 11 where the end-cooling effect is by no means negligible. However, similar changes in section are often encountered in production parts and the tests are of value for that reason. (The difference in hardness of corresponding sections of the step-down bars quenched in the two mediums is more pronounced than for the teeth of the gears described above, due to the relatively light section of the latter.)

Table II also indicates that shafts of 2-in. diameter or larger that require a high surface hardness should not be made of 8620 steel if they are to be martempered in the way we perform this operation. Many mainshafts, with surfaces serving as a raceway for needle bearings between the shaft and the gear revolving on it, fall into this category, and if hot oil quenching is specified, these shafts are made of 4320 steel.

Conclusion

It may be concluded that hot bath quenching constitutes a practical and economical means of controlling the dimensions of many carburized production parts during hardening. It is not a cure-all, however, and should not be expected to compensate for relaxed standards in other phases of manufacturing, such as annealing or gear cutting. Also, there are some limitations of the process that should be recognized, particularly in regard to the hardness obtainable with large sections of low-alloy steel. A careful analysis of each part and its function should be made in order to determine if hot bath quenching is feasible.

Editor's Note: A subsequent article is promised on the treatment of carburized gears left in the furnace over the week end.

Table II — Hardness-Penetration Data for Disks Cut From the Carburized and Hardened Step-Down Bars of Fig. 10

Column headings are respectively Section Diameter, Steel, and Bath Temperature in °F.

Inches From Surface	1 In.				2 In.				3 In.				4 In.			
	4320		8620		4320		8620		4320		8620		4320		8620	
	130	350	130	350	130	350	130	350	130	350	130	350	130	350	130	350
0.0	C-64	C-64	C-64	C-62	C-64	C-63	C-62	C-59	C-64	C-63	C-63	C-55	C-64	C-62	C-63	C-57
0.010	62	62	63	61	61	60	63	60	61	61	62	58	61	62	62	60
0.020	61	61	61	55	60	59	60	48	59	59	58	48	60	60	60	51
0.030	57	58	55	46	56	54	52	38	55	54	50	40	56	55	52	41
0.040	52	52	47	38	50	41	42	33	49	49	41	35	49	44	41	34
0.050	47	46	38	32	44	35	36	30	34	35	32	30	42	36	36	30
0.060	43	40	34	29	39	32	31	27	30	32	30	27	38	34	32	27
⅛	37	32.5	25	20	31.5	26.5	22	B-96	31	25	21.5	B-97	31	27	23.5	21.5
¼	35	31	23	20	28.5	24.5	B-96.5	95.5	27	24.5	B-96	95.5	27.5	26	21	20
⅜	34.5	31	22	20	26.5	24.5	96	94.5	25.5	24.5	94.5	94.5	26	25.5	20	B-96
½	35	32	22	20	25.5	25	96	93.5	24	24	93.5	93.5	24.5	25.5	B-96	96
⅝					25.5	24.5	95	93	24	23	92.5	92.5	24	25.5	94.5	96
¾					26	25.5	94	93	23.5	23.5	92	92	23.5	25.5	93	95
1					28	25.5	93	93	23	23.5	89.5	89.5	23.5	24	90.5	92.5
1¼									23	23.5	88.5	89	23	24	89.5	91.5
1½									23.5	24	87.5	87.5	23.5	23.5	88.5	90
1¾													23.5	24	88	89.5
2													23.5	23.5	86.5	88.5

All hardness readings were originally Rockwell C-scale and those under the rules were converted to Rockwell B-scale.

How to Find Detailed Information When You Want It

By A. H. Geisler
Research Associate
General Electric Research Laboratory
Schenectady, N. Y.

A complete classification of the metallurgical field has been devised by a committee sponsored by the American Society for Metals and the Special Libraries Assoc. It has already been adopted by the A.S.M.'s Review of Metal Literature, and is especially applicable to an improved punch card, whereby any information on file concerning any minor subdivision of the metallurgical field can be quickly located with the simplest imaginable equipment.

WITH the ever-increasing mass of technical literature in the various branches of the field of metallurgy, it has become apparent that a simple yet efficient method of gaining access to the information is to be desired. The A.S.M.'s Review of Metal Literature published monthly in *Metals Review* satisfies part of this need, for it provides a readily available abstracting service covering the entire field of metallurgy. This complete and unique coverage of both ferrous and nonferrous physical and process metallurgy, as well as its *prompt* publication, allows the busy metallurgist to keep abreast of current developments in his field. However, a second requirement — that of having the information accumulated during the past few decades readily available — is also desirable. To meet this need, three systems of filing literature and their application to punch cards for filing abstracts have been described in these pages in a little over two years.* While these systems have been accepted and used by a few, it is thought that many more potential users have been awaiting a more universal system sponsored by a national society such as A.S.M. with the ensuing uniformity and complete coverage which it might offer.

Your society has met this responsibility as evidenced by the following brief description of the new system. After 15 months of deliberation, a committee sponsored jointly by the American Society for Metals and the Special Libraries Assoc. has concluded its task of formulating a scheme for the classification of metallurgical literature. Its work was facilitated by the existing schemes, by the many helpful comments received from more than 50 commentators on a preliminary outline circulated last summer, and by the breakdowns which were available for special fields such as foundry, welding, corrosion, and powder metallurgy.

Members of the committee were (chairman) T. D. Yensen, manager, magnetics department, research laboratories, Westinghouse Electric Corp.; Mrs. M. R. Hyslop, editor of *Metals Review* (who acted as secretary); A. H. Geisler, research associate, General Electric Research Laboratory; H. P. George, metallurgist, Frankford Arsenal; W. W. Howell, technical abstractor, Battelle Memorial Institute; R. W. Kollar, librarian, Fenn College; Taylor Lyman, associate editor of *Metal Progress* and editor of "Metals Handbook"; F. T. Sisco, director of Engineering Foundation; Miss M. S. Wright, librarian, National Carbon Co.

*"A Punch Card Filing System for Metallurgical Literature", by A. G. Guy and A. H. Geisler, *Metal Progress*, Vol. 52, 1947, p. 993.

"A Modified Punch Card Filing System for Metallurgical Literature", by J. H. Westbrook and L. H. DeWald, *Metal Progress*, Vol. 54, 1948, p. 324.

"Punch Card for the Field of Metal Finishing", by T. A. Hood, *Metal Progress*, Vol. 56, 1949, p. 75.

The objective of the committee was to derive a classification system with a three-fold purpose:

1. To provide a logical and fairly simple breakdown of the entire metallurgical field which can have universal applications in classifying the literature.

2. To serve as a guide for a punch card filing system that can be used by the individual metallurgist for his own reference collection.

3. To be used as a pattern for classifying the abstracts published in the A.S.M. Review of Metal Literature.

Of these three purposes, the second — a punch card filing system — required the most extensive development and the balance of this article will be devoted to a discussion of how it was achieved.

One attractive feature of a punch card system for filing literature abstracts is that the reference can be coded in a number of ways to accomplish an interrelation of ideas without requiring duplicate cards. The cards can then be sorted in any one of these ways to obtain the desired information. Thus, one problem of the committee was to decide upon the discrete ways in which the literature can logically and completely be classified. These form the bases of the four indexes chosen.

Metallurgical literature usually refers either to *(a)* a material, or *(b)* a process, property or field of use. These form the two main subject indexes which will be useful in any branch of the field of metallurgy. Thus, one policy of the committee was to divorce process or property from material and to treat each at equal par on the separate indexes. The second policy was to make the indexes general, with a uniform and descriptive coverage, and with adequate provisions for expansion at every point (as desired by the users). Finally, the outline for use with the punch card does not require that subjects be divided into "pockets" of equal importance or unique meaning, and departures were occasionally made from the form of the logical outline where indicated by common sense.

Index of Processes and Properties

The one subject index (which many users will consider to be the main index) provides for 29 first-order or main divisions classified according to metallurgical processes, inspection, and properties. Twenty titles have been chosen by the committee, and nine extra are available on the punch card for future expansion or for the user's special needs. The committee's 20 are given letters as follows:

A. General Metallurgical
B. Raw Materials and Ore Preparation
C. Nonferrous Extraction and Refining
D. Ferrous Reduction and Refining
E. Foundry
F. Primary Mechanical Working
G. Secondary Mechanical Working
H. Powder Metallurgy
J. Heat Treatment
K. Joining
L. Cleaning, Coating and Finishing
M. Metallography, Constitution and Primary Structures
N. Transformations and Resulting Structures
P. Physical Properties and Test Methods
Q. Mechanical Properties, Tests and Deformation
R. Corrosion
S. Inspection and Control
T. Applications of Metals in Equipment
U. Allied Fields
V. Material Only Indexed

The punch card arrangement selected allows *each* of these main divisions to be subdivided into a maximum of 27 second-order divisions. Those supplied by the committee occupy, on the average, about half of these, thus leaving 50% for expansion at the second-order level. Provisions have also been made on the card so that each second-order subject can be further subdivided into 16 third-order divisions and each of these in turn into 15 fourth-order divisions. A few of the third-order divisions (but none of the fourth-order) are listed by the committee to give a uniform and reasonably detailed breakdown adequate for the average user. (Metallurgists in specialized fields may prefer to add to or revise one or two main divisions.)

F. Primary Mechanical Working

21. **Preparation for working**
    (For pickling see L12; for blasting, see L10c)
    a. Stripping
    b. Heating
    c. Scalping
    d. Chipping
    e. Torch scarfing
22. **Forging** (hammer and press)
    g. Rough
    h. Cutting or slicing
    j. Upsetting
    k. Punching or coring
    m. Hollow forging
    n. Drop forging
23. **Rolling**
    n. Breakdown
    p. Intermediate shaping
    q. Finish rolling
    r. Temper rolling
24. **Extrusion**
    a. Direct
    b. Inverted
25. **Swaging**
26. **Tubemaking** (and pipe)
    n. Seamless (piercing, sinking, drawing, rolling)
    p. Pressure welded
27. **Drawing of rod**
28. **Wire drawing**
    g. Single draft
    h. Continuous
29. **Finishing operations**
    (For cleaning and polishing see Section L; for heat treatment see Section J)
    n. Slitting
    p. Sawing
    q. Shearing
    r. Straightening
    s. Flattening and leveling
1. **Lubricants**

A typical breakdown showing second and third-order divisions as worked out by the committee is as shown at the bottom of the left-hand page. Capital letters are used for the first-order divisions, numerals for second-order, lower case letters for third-order and numerals (starting at 30) for fourth-order divisions. Thus, the code for *drawing of seamless pipe* might be F26n32.

When fully expanded, the Processes and Properties Index will accommodate, in addition to the 29 first-order divisions, 756 second-order divisions, 12,096 third-order divisions and 181,440 fourth-order divisions, numbers which certainly will be adequate for expansion regardless of the amount of detail added by the user. Special fields of importance may be indexed either by adding more third-order and fourth-order divisions, or the user may take his specialized field and advance it to an unused first-order position, such as W. For example, a metallurgist who specializes in magnetic materials may wish to advance P6 to create **W. Magnetics**, or one who is specifically concerned with the theory of the heat treatment of steel may wish to take the second-order division N8 and make it **X. Austenite Transformation.**

The Materials Index

Provisions have also been developed so that information about metals and alloys may be indexed both by composition (elements) and by industrial group. This is done on a single index which involves no duplication:

Ag. Silver and Its Alloys
Al. Aluminum and Its Alloys
C. Carbon and Carbides
Co. Cobalt and Its Alloys
Cr. Chromium and Its Alloys
Cu. Copper and Its Alloys
Fe. Iron and Its Carbon-Free Alloys
Mg. Magnesium and Its Alloys
Mn. Manganese and Its Alloys
Mo. Molybdenum and Its Alloys
Ni. Nickel and Its Alloys
Pb. Lead and Its Alloys
Si. Silicon and Its Alloys
Sn. Tin and Its Alloys
W. Tungsten and Its Alloys
Zn. Zinc and Its Alloys
EG. Other Elements and Their Alloys
SG. Special Groups by Use
ST. Steel — General
CN. Carbon Steel
AY. Alloy Steels
SS. Stainless Steels
TS. Toolsteels
CI. Cast Irons and Cast Steels

The designation EG (for "elements grouped") includes the other 80 elements of the periodic table coded individually while SG (for "special groups") is subdivided into groups such as heat resisting alloys, bearing alloys and magnetic alloys. Seven unlabeled holes are left in the punch card for expansion so that materials such as titanium or corrosion resisting materials may be advanced to first-order positions, if such would meet the individual's needs. Further breakdown of the materials by group is accomplished by 16 second-order divisions each with 15 third-order divisions to provide a total of 240 subdivisions for each of the groups of alloys listed above. This permits the coding of individual trade names if desired.

The Common Variable Index

A further and finer classification of the literature can be attained on the punch card system by grouping miscellaneous features or factors into a separate index. Such features, common to a large bulk of the metallurgical literature, can be divided into three basic types, as follows:

A. Characteristics of the publication
   - Type and form (theory, review, patent, book)
   - Source (specific laboratory, plant, research organization, or university)
   - Date
   - Language

B. Factors which refer to processes and properties
   - Equipment (design, furnaces, fuels)
   - Techniques and methods
   - Influencing factors (effect of grain size, temperature, past history)

C. Factors which refer to materials
   - Metal forms (wrought and cast shapes)
   - Defects

Since the choice of such common variables will largely depend upon the need and upon the field of specialization of the individual metallurgist, the committee formulated only a suggestive list and three possible schemes to illustrate how these may be handled.

The Author Index

After reviewing numerous methods which have been proposed for indexing the author's name, a new method was developed which combines simplicity, ease of operation, selectivity, and economy of space. Frequency of the various letters as the first, second and third in metallurgists' surnames was determined from those listed in A.S.M. Review of Metal Literature and the British Metallurgical Abstracts. Certain letters could be conveniently grouped for indexing the first and third letters of the names, whereas the second letter was usually a vowel. A compact index was derived whereby the first three letters of the name (of one or two authors) can be indexed with one punching per letter.

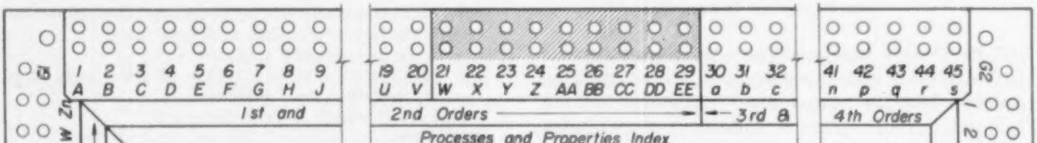
The New Punch Card

The most popular size of punch card for filing bibliographic references measures 5 by 8 in. To make the new system work most efficiently, it was necessary to adopt a card with more closely spaced holes — six double holes per inch instead of the more usual four. Portions of the new card bearing the printed designations are shown in Fig. 1. The entire top edge of the card is devoted to the Processes and Properties Index. First-order divisions are coded by a deep punch and second-order by a shallow punch on the field at the left, while third-order divisions are indexed by a deep punch and fourth-order by a shallow punch on the field at the right. The tinted portion, holes 21 to 29 inclusive, are for expansion by individual specialists, these positions being left open in the committee's classification. The corner holes marked G_1 and G_2 are for "General" subdivisions of first-order and second-order divisions, respectively.

The Materials Index occupies the left edge and left half of the bottom edge. The common elements, elements grouped (EG), "open" space for expansion, and special groups (SG) are on the left edge whereas the ferrous groups and third-order and fourth-order field are on the bottom edge. The dual operation of this Materials Index is relatively simple: To index *by elements*, a deep punch is made for base metal and shallow punches for alloying additions direct (or in EG, as used on earlier schemes for classifying metallurgical abstracts). To index *by group*, a deep punch is made for base metal or specific group, while subsequent breakdown is made by code on the third- and fourth-order field. The latter will also be used in combination with EG when indexing for an element that is not among the 16 common elements with specific holes.

The dog-eared half of the bottom edge is devoted to the Author Index. The first and third letters of the author's surname are indexed by a deep and shallow punch, respectively, on the larger field at the right. The second letter is indexed by a deep or shallow punch as required on the three holes at the center.

Finally, the 25 holes along the right edge of the card are allotted to the Common Variables Index. The possible methods of using this space are almost unlimited. If the user prefers, 24 main



Cut-Down View of New Punch Card Showing Arrangement and Designation of Holes

divisions (each with 23 subdivisions or a total of 552 subdivisions) could be used, following the scheme of the Process and Properties Index where two operations are required to designate a second-order subdivision. At the other extreme, 48 divisions could be used with a single punch per division and no limit on the number of features which could be simultaneously indexed. The end hole marked "duplicate" (DUP) would be punched if both a deep and a shallow punch were required on the same double hole. If it were desirable to index a date, the first ten holes could be used to index directly year and decade while the remaining 14 holes could be used for other common variables. (In this scheme, DUP would be punched if the year and decade were the same, as in 1944.)

Operation and Adaptation to the Old Card

The operation of a normal punch card system has been described in detail by the present author in this publication for December 1947, and need not be reviewed. Certain of its features were retained without any sacrifice in the new ASM-SLA classification system, which in turn can be adapted to the card proposed originally. The committee's Processes and Properties Index could be assigned to top and right edge of the old card using the space for its analog — the Subject Index of the older system. First-order and second-order subdivisions in the committee's classification would use holes 1 to 29, on the top of the old card, third-order and four-order subdivisions would use holes 30 to 45. The single hole E in the old card would be used for G_1 and 46 for G_2. The committee's Materials Index would use the left side of the old card for the common elements and base metals as originally (using π instead of EG), and the right edge of the old card for the committee's breakdown of the element and alloy groups. One of these divisions would be for the unalloyed metal, thus eliminating the need for hole E in the old card. Along the bottom of the old card provisions were made for only three common variables: T. Theory; A. Application; and G. General. The author index, accommodating only the first two letters of the author's surname, need not be changed.

Advantages of New Card

While it is possible to adapt the new system to the older card, the new card has several unique advantages: First, it provides spaces for indexing directly the special groups and ferrous groups of alloys in the materials index, and still leaves some extra holes for adding other materials at first-order level. It also provides a separate field or portion of the card's edge for the breakdown of material groups. (This will reduce appreciably the number of unwanted cards that would be obtained if both subject indexes used the same higher-orders' field.) Second, the best performance of the Common Variable Index can be attained only with the new card; the selectivity so obtained can only be appreciated by the user when he develops the index to meet his special needs, whether he wishes to use the common variables to describe the publication or to list features that modify the subject indexes. Finally, the newly devised author index permits appreciably greater selectivity.

Equipment and Supplies

The complete classification, together with a detailed explanation of its uses for both punch card operation and for the more familiar library filing systems is being published in book form by the American Society for Metals.

An alphabetical word index (cross index) with the appropriate code designations has been prepared from various metallurgical glossaries such as the main index of Metals Handbook. The book will also include two forms of the Materials Index, one a brief form with rather broad subdivisions, and the other a much more detailed form. The policy of the committee here again was to provide flexibility so as to cover the needs of all potential users. These indexes are designed so that the metallurgist who is interested principally in only one or two metals can use the detailed form for these metals and the broad form for the others in which he is interested in only a general way.

A separate set of looseleaf "work sheets" can be ordered; they have been designed to provide a highly flexible method of utilizing the enormous capacity of the indexes. These looseleaf pages are arranged so that additions can be easily made to any sections — or entire sections could be revised to suit the needs of the user. Third-order and fourth-order divisions can be added by form sheets already bearing, in part, the code designations. The printing is such that additions can be made on a standard typewriter. Thumb-index tabs can easily be attached for the main divisions.

Coded designations have been printed on the abstracts in *Metals Review* since the February issue. The abstracts of interest to the metallurgist can now be marked by him, then clipped, cemented to a punch card, and the cards punched by clerical help. Equipment such as the cards, the punch, the sorter, the book and the work sheets will be sold at cost, so that A.S.M. members can benefit from the large-quantity purchases made by the society.

A New High-Strength Aluminum Die-Casting Alloy

By J. J. Warga, J. J. Preisler
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Engineering Division
Sperry Gyroscope Co.
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In this example the metallurgist's problem was to devise an aluminum alloy that could be die cast and that would have elastic strength higher than any available aluminum die-casting alloy. The problem was solved by adding silicon to an Al-Mg-Zn alloy that had been used previously in the form of investment castings.

THE motivating factor behind development of new alloys is the ever-increasing demand for improved properties to suit more rigorous product applications. This challenge is properly the concern of the metals producer, but occasionally it becomes necessary for the consumer to develop a new alloy or modify an existing one in order to satisfy a particular design or manufacturing requirement. Such an occasion will arise, for instance, when the metallurgical engineer is confronted with the situation known as "frozen design", which prevents the ideal approach of simultaneous consideration of design, materials and manufacturing methods.

This article describes a specific example where the need for increased elastic strength and reduced manufacturing cost led to the development of a high-strength aluminum die-casting alloy.

Need for High Elastic Strength — For many types of equipment, the usefulness of a part is destroyed when it has been permanently deformed; that is, when its elastic limit has been exceeded. For such parts the elastic limit, rather than the offset yield strength or the ultimate tensile strength, becomes the design criterion. This is particularly true of precision instruments, where the need for accurate and reproducible readings under all conditions of operation is of paramount importance. For instruments used in aircraft, there is the added consideration of light weight.

The need for a light alloy of high elastic strength presented itself recently for a gimbal ring used in several of the instruments manufactured by the Sperry Gyroscope Co. A gimbal ring, it should be explained, is used to support a spinning gyroscope and is in turn mounted in a spindle at right angles to the direction of support of the gyroscope in the gimbal. By means of this mechanical coupling, the gyroscope remains free to rotate in any direction with respect to a fixed datum, usually the earth, and indicates the proper attitude of the aircraft with respect to that datum. The demands made on the strength of the gimbal are quite high because during sudden maneuvers a load of up to 10 G's (10 times the acceleration due to gravity) may be imposed.

The gimbal ring, subject to the factors of minimum size and weight and maximum strength, was designed as shown in Fig. 1, to be made as an investment casting. The material originally selected was an aluminum alloy containing 7% silicon and 0.25% magnesium, similar to Alcoa 356. This alloy was chosen because of its generally good foundry characteristics and its good strength and dimensional stability in the aged (T51) condition.

The instruments containing the gimbal ring were placed in service and found acceptance in the aircraft industry to an extent that the quantities to be manufactured justified the use of a die casting for that particular part. Accordingly, a die was manufactured, and a 3.5% copper, 8.5% silicon

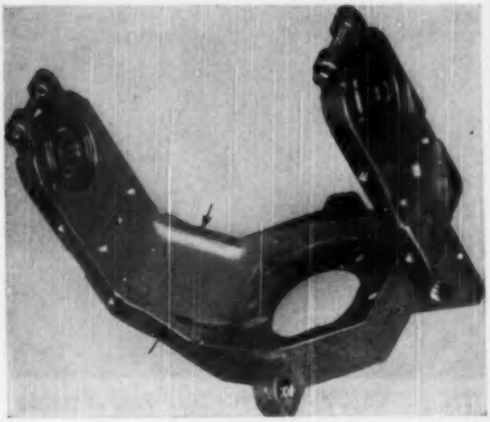

Fig. 1 — Gimbal for Flight Instrument, Showing Ball-Bearing Assembly for Mounting High-Speed Gyroscope. Arrows indicate ribs added for greater strength

aluminum alloy similar to Alcoa 380 was specified. After work on the die had been almost completed, field reports indicated that the arms of the gimbal were springing apart slightly on instruments subjected to unusual service conditions at high speed.

Upon receipt of this information, the processing of the gimbals in manufacture was revised to provide for solution heat treatment and age hardening of the 356 alloy (T6 condition) in order to secure higher strength. At the same time, a test program was initiated to locate the section where failure was most likely to occur. By means of load-deflection tests, it was determined that failure would occur at the base of the two arms, and accordingly these points were strengthened by adding ribs, as indicated by the arrows in Fig. 1. These changes produced a marked improvement, and would probably have been satisfactory for the application, had it not been for the fact that the water quench from the solution heat treating temperature introduced residual stresses that caused dimensional changes too great to be tolerated.

Consideration was then given to the ternary aluminum-magnesium-zinc alloys which are capable of high strengths without solution heat treatment, so that quenching could be avoided during processing. A study of the properties of these alloys indicated that the required condition of high elastic strength could be obtained, and even exceeded, through the use of the aluminum alloy known as Ternalloy 8.* Load-deflection tests of this alloy in the stabilized condition verified this fact. The proportional-limit loads of gimbals made from this alloy and from Alcoa 356 and 380 are shown in Table I, along with published mechanical properties for these alloys.

A quantity of gimbals was satisfactorily manufactured in Ternalloy 8 as precision investment castings. In the meantime, the design changes which had evolved during the testing program on the investment-cast gimbals were incorporated into the design of the die castings. No trouble was anticipated with die-cast gimbals since considerable increase in strength occurred primarily from the design change, and the die-casting alloy, Alcoa 380, has slightly higher properties than Alcoa 356-T6. However, when load-deflection tests were made on gimbals die cast from alloy 380, the elastic-limit load was found to be less than half as high as the values obtained in alloy 356-T6, and one third as high as those obtained with Ternalloy 8. Production requirements were now such that gimbals could no longer be manufactured economically by the investment process and at the rate required. It appeared that an impasse had been reached, since no stronger aluminum die-casting alloy was to be had, and further redesign of the gimbal to increase the resistance to permanent set would have involved changes in the entire gyroscope mounting, which would not have been feasible.

It was then decided to try die casting the high-strength ternary alloys. The aluminum-magnesium-zinc alloys as a group are characterized by sluggishness during casting and by a tendency

*Nominal composition: 2.3% magnesium, 4.9% zinc, 0.5% manganese, 0.3% chromium. Produced by Apex Smelting Co., Cleveland.

Table I — Limit Loads of Aluminum Alloy Gimbals

Alloy	Condition	Average Load at Proportional Limit	Typical Yield Strength, 0.2% Offset	Typical Ultimate Strength	Typical Elongation
356*	Stabilized	30 lb.	17,250 psi.	24,000 psi.	2.5%
356	H.T.A.†	130	22,000	34,000	4.5
Ternalloy 8	Stabilized	155	30,000	38,000	0.5
380	As die cast	54	26,000	38,000	1.5

*Old design without ribs. †H.T.A. = Solution treated and aged.

toward hot shortness; they are not generally considered suitable for die-casting operations. Trial runs in the die-casting shop confirmed the sluggishness of these alloys. Even the use of the maximum pressure in the high-pressure die-casting machine was insufficient to obtain proper fill. When the temperature of the molten metal in the holding furnace was increased so that greater fluidity could be obtained, hot cracks and tears resulted, despite any variations of die pressure, die temperature, time of holding in the cold chamber, and speed of injection. In addition, the molten alloy wet the in-gate and faces of the dies, and soldering resulted after only a few shots.

Addition of Silicon to Al-Mg-Zn Alloys

Silicon is generally advantageous in aluminum alloys because of the excellent casting qualities that result from its addition, manifested principally by superior fluidity at low casting temperatures and pressures, and freedom from hot shortness. Why not, then, add silicon in an amount sufficient to achieve the desired die-casting characteristics? Available information regarding its effect on sand-cast or permanent-mold-cast Al-Mg-Zn alloys indicated that its inclusion in excess of the usual limiting value of 0.20% decreased the elongation and prevented normal room temperature hardening.

No information was available for additions over 1.0%, and none for the conditions encountered in die casting. For these reasons, it was decided to proceed with the addition of silicon. A charge of Ternalloy 8 was melted in a 25-lb. crucible, and 25% silicon-aluminum hardener was added to produce a composition of 1½% silicon. After the addition of the hardener, the charge was heated to 1550° F. and held for 15 min. to dissolve the silicon thoroughly. The charge was then cooled to 1250° F. and degassed with nitrogen, after which it was cast. The die fill was good, but trouble was encountered with cracking in two of the critical sections of the casting. Further charges were made up to 2½, 3½ and 4½% silicon, repeating the melting and casting procedures. Silicon additions of 2½% or more produced an alloy that flowed freely, filling out the die cavity and producing crack-free castings of excellent surface appearance without sticking or soldering of the molten alloy to the die faces.

The same procedure was followed with alloy 40E.* With this alloy, even the addition of 5% silicon did not entirely eliminate "gumminess" and soldering in the in-gate. In addition, the elastic limit was considerably lower than for the modified Ternalloy 8.

*Nominal composition: 0.6% magnesium, 5.5% zinc, 0.5% chromium, 0.2% titanium. Produced by Frontier Bronze Corp., Buffalo, N. Y.

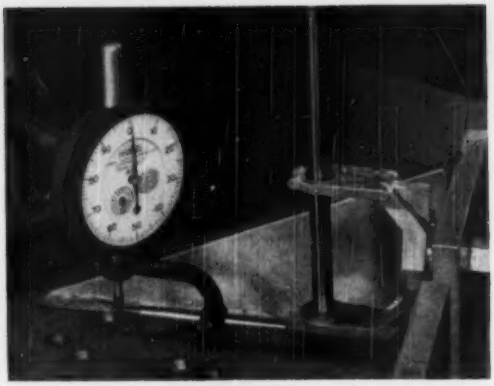

Fig. 2 — Setup for Load-Deflection Tests on Gimbal

A heat of 160 lb. of silicon-modified Ternalloy 8 (2½% Si) was then made and tried under regular continuous production conditions. Shrinkage cracks occurred, and therefore more silicon was added. By means of the production check, it was determined that the addition of 4½% silicon produced the most satisfactory results in processing.

Tests on Quaternary Alloy

In order to determine the acceptability of the new alloy for the service and manufacturing requirements desired in this part, a quantity of the die-cast gimbals were subjected to systematic laboratory tests. Mechanical properties, dimensional stability, machinability, ability to be anodized, resistance to salt spray, and resistance to stress-corrosion cracking were checked.

For the gimbal application, the most important mechanical property of the new alloy is the elastic or proportional limit. The slightest amount of permanent set is detrimental to correct operation. Since a die for casting tensile test bars was not available, mechanical tests were made on the gimbals and the results compared with similar test data previously obtained with other alloys.

The gimbals were placed in a fixture as illustrated in Fig. 2, and a measured load applied to the arms by means of a rod attached to the weighing head of a hydraulic testing machine. The deflection was determined by reading a dial extensometer coupled to the lower surface of the arm through a lever, and load-deflection curves were derived. The proportional-limit load was taken at the point of departure of the curve from a straight-line relationship. For convenience, the propor-

tional limit rather than the elastic limit was determined, as the two are very close.

The gimbals were tested in the as-cast condition, as stabilized for 4 hr. at 390° F., and as solution heat treated and aged at 390° F. The results are shown in Table II. Solution heat treatment was performed for information only; die castings are seldom heat treated in production because of the danger of blister formation.

The simple aging treatment at 390° F. was of most interest to us, as it was desired to relieve residual casting stresses, and in addition, to stabilize the alloy so that the mechanical properties would remain unchanged during subsequent room temperature aging. Measurements made at successive time intervals after stabilizing showed that the dimensional stability was equal to that of the investment-cast gimbals made from Ternalloy 8.

Table II — Limit Loads of New Die-Cast Alloy Gimbals

Silicon Content	Condition	Average Load at Proportional Limit
2½%	As Die Cast	110 lb.
2½%	Stabilized at 390° F.	165
2½%	Solution Treated and Aged	195
4½%	As Die Cast	70
4½%	Stabilized at 390° F.	185
4½%	Solution Treated and Aged	200

A number of die-cast gimbals were permitted to age at room temperature to see whether hardening would be inhibited by the addition of silicon. These last samples were not tested in deflection, but were checked for hardness over a period of six months. The results are plotted in Fig. 3.

It may be seen from Table II and Fig. 3 that the addition of silicon in excess of 1½% to the ternary alloy does not inhibit hardening either at room temperature or at elevated temperatures. It may further be seen by comparing Tables I and II that the proportional-limit load of the stabilized gimbal in the quaternary alloy exceeds the value obtained with investment-cast Ternalloy 8, which was also stabilized. Solution heat treatment and aging increased the limit load still further. The new alloy has an elastic strength four times as high as that for alloy 380. From the standpoint of strength, then, it was evident that no malfunctioning of the instrument would occur from the use of the new alloy, which we call Sperry alloy 37.

An approximate measure of the ductility was obtained by continuing the deflection test of the arms until fracture occurred. The amount of deflection, and the fractured surface, were compared with similarly tested gimbals of Ternalloy 8 and alloy 380. The deflections of Ternalloy 8 and alloy 37 were identical; alloy 380 was much higher. Since investment-cast Ternalloy 8 gimbals performed satisfactorily under service conditions, it was felt that the ductility of alloy 37 was adequate.

The ternary aluminum-magnesium-zinc alloys are among the most machinable of the aluminum alloys. It was found by routing about 25 of the new die-cast gimbals through the regularly scheduled machining operations that the machinability was equivalent to Ternalloy 8. Fine finishes could be attained, and drilling and tapping performed with no revision of machine settings and standards.

Several die-cast gimbals were processed through the sulphuric acid and chromic acid anodizing baths. No difficulty was encountered in securing uniform anodic coatings similar to those on Ternalloy 8.

The corrosion resistance was determined by exposing samples to salt spray tests in the anodized and unanodized conditions. The anodized samples passed the requirements of Army-Navy Aeronautical Specification AN-QQ-A-696, which calls for resistance to 250-hr. exposure. The unanodized samples, however, were found to be slightly inferior in corrosion resistance, as compared with Ternalloy 8 and alloy 380.

Susceptibility of the new alloy to stress-corrosion cracking was also investigated. Bearing housings and bearings were mounted in the holes in the ends of the arms of the gimbal, and clamped in place as shown in Fig. 1. The clamping screw was tightened using a torque screwdriver, and loads corresponding to 30, 60 and 90% of the proportional limit of the material were applied.

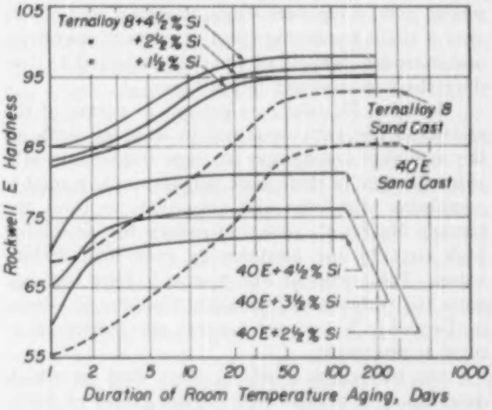

Fig. 3 — Aging of Die-Cast Al-Mg-Zn-Si Alloys

The clamped gimbals were then exposed to a 10-day humidity cycle consisting of 6 hr. at 150° F. and 95% relative humidity, followed by cooling to room temperature conditions in 18 hr. All specimens passed this test except one stressed to 90% of the proportional limit, which failed at the end of 7 days. This was considered good, as the investment-cast Ternalloy 8 gimbals failed at 60% of the proportional limit within 5 to 6 days.

In view of the favorable results obtained, it was decided to release the new alloy for use in the production of gimbals. A typical composition of alloy 37 as finally adopted is:

Silicon	4.3%
Magnesium	1.8%
Zinc	3.5%

In addition, the alloy contains 0.1% copper, 0.2% chromium, 0.3% iron, 0.4% manganese, 0.03% nickel, and 0.07% titanium. To date, about 2000 gimbals have been die cast in a Lester-Phoenix cold chamber machine at 26,000-psi. pressure, processed through the shop and placed in service.

Metallurgical Considerations

In the desire to release the new alloy for production as quickly as possible, little opportunity was afforded to study its microstructure in detail. Published data on the phase relationships applying to the Al-Mg-Zn-Si quaternary system are meager, and are not considered relevant because the ternary phase $Mg_3Zn_3Al_2$ has been neglected. This ternary phase is a precipitation hardening agent of considerable power, and is responsible for the high strength of the Ternalloys.

Magnesium, under equilibrium conditions, will combine more readily with silicon to form Mg_2Si than with aluminum and zinc to form the ternary phase. The compound Mg_2Si, however, contributes only a slight hardening effect at room temperature, and extended periods of time are required to produce the improvement in hardness.

In alloy 37, silicon is present in excess of the stoichiometric ratio required to combine with all the available magnesium to form magnesium silicide. In spite of this, some magnesium is probably combining with zinc and aluminum to form the ternary $Mg_3Zn_3Al_2$ phase necessary for producing high strength and hardness by room temperature aging. The curves of Fig. 3 seem to bear this out, since the addition of increasing amounts of silicon to Ternalloy 8 does not repress age hardening at room temperature.

On the other hand, in alloy 40E in which magnesium is present only to the extent of 0.6%, silicon reduces the ultimate hardness of the alloy, although a pronounced hardening effect still occurs.

Equilibrium is not attained under the conditions of rapid cooling that occur in die casting, so that both phases co-exist, provided a certain threshold limit of magnesium or zinc is present. Micrographs are shown in Fig. 4. It is hoped that future investigation will clarify the effects of composition on microstructure.

Additional Test Work

Future test work has been planned, in which the ratio of silicon to magnesium to zinc will be varied between wide limits in order to determine the optimum composition with regard to mechanical and other properties of the alloy. Preliminary experiments on alloys containing no zinc and on others containing no magnesium indicate that both

Sperry Alloy 37 Aged 4 hr. at 390° F. — Ternalloy 8 Aged 15 hr. at 310° F.

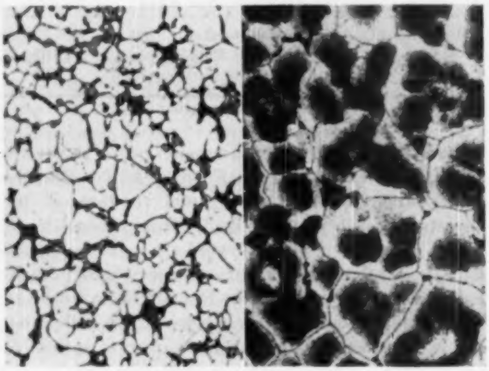

Fig. 4 — Microstructures at Critical Section of Gimbal. Keller's etch. 250× (Micros by H. Griffen)

these elements must be present to secure the high elastic properties. The need for chromium, titanium and nickel is not apparent at present, but they may be necessary for specialized properties.

The future work will be conducted on die-cast tensile test bars conforming to A.S.T.M. dimensions so that the mechanical properties can be developed in a form usable for engineering design. Stress-corrosion cracking and aging response are also to be studied, and metallographic examination may establish alloy partition and phase relationships. It is hoped that out of this work will evolve an aluminum die-casting alloy that has an optimum combination of engineering properties for this class of material.

Critical Points

By The Editor

NATURE denied America, which she favored in so many ways, any workable deposits of columbium or tin. These two are coupled because nearly all the columbium comes from tin placers in Africa. (Nobody needs to be reminded of the tin can's importance.) Columbium — unknown commercially 20 years ago — is the favored element for stabilizing 18-8 against "weld decay", and really becomes strategic in the production of strong alloys for the hot spots in jet engines. The growing tonnage of these alloys for gas turbines, which may contain up to 4½% Cb, has led to a critical problem in supply, since the earlier use for columbium in stabilized 18-8 (Type 347) has in the past consumed most of the world's production. This for America's consumption of Type 347 alone.

It is not surprising, therefore, that attention was turned as early as 1934 to tantalum, a metal twice as heavy as columbium but exactly below it in the periodic table of elements, and therefore likely to have quite similar metallurgical effects. In fact, the columbium concentrates (ores) being imported from Nigeria usually contain 5 to 10% tantalite and the standard American ferrocolumbium has analyzed about 40% iron, 55% columbium and 5% tantalum. "Pure" tantalite for the equally strategic tantalum metal is also rather rare; on the other hand, comfortable quantities of mixed columbite and tantalite (Cb_2O_5 and Ta_2O_5) in the 2 to 1 ratio are available. The metals are very hard to separate chemically; it would be nice if they were equally potent in their specific metallurgical effects.

Columbium or tantalum? or both?

This seems to be true. For example, the 4% columbium in a melt of heat resisting S-816 alloy was entirely replaced by metallic tantalum and the stress-rupture tests were on the high side of the scatter band for the conventional alloy. Similar substitution for the 0.85% Cb in Type 347 gave a stainless sheet that corroded at about the same rate in the standard nitric acid tests. A preliminary conclusion is, therefore, that a ferrocolumbium-tantalum made from mixed oxides and analyzing 40% iron, 40% columbium and 20% tantalum will be equally effective in the alloys used at present, when the quantity added corresponds to the fact that tantalum's atom is twice as heavy.

Such a conversion from 10:1 Cb:Ta ferro-alloy to a 2:1 Cb:Ta ferro, no matter how desirable from a conservation standpoint, will require a deal of work in the chemical, petroleum, aircraft and gas turbine industries. Especially in the latter two will prototypes need to be made, installed, block tested and flown. This takes time — also official approval from the Air Forces. To be forward in the matter, the Society for Automotive Engineers' quasi-official Committee on Aeronautical Materials has already modified the so-called A.M.S. specifications to include materials made with the Cb-Ta mixtures. Also: Much stainless containing columbium is probably now used for high-temperature work, "just to be safe", in places where it is not necessary. An early attempt to find out the *actual* requirements in service might pay great dividends in an emergency.

On the basis that Type 347 steel is of prime use to resist liquid corrosion rather than high-temperature gases, the processing industries would do well to support generously The Engineering Foundation's investigation on the resistance of welded sheet to service conditions. If the facts are known, much of the columbium in stabilized 18-8 can be eliminated, either by using titanium-stabilized sheet (Type 321) for those purposes where its corrosion resistance is sufficient, by stabilizing the present extra low-carbon grades of 18-8 with a proportionately smaller amount of Cb-Ta, and possibly driving the carbon down to 0.02% — so low that additions are unnecessary.

AT NATIONAL STEEL CAR CO. of Hamilton (Canada) found an interesting application of the "stretch-forming" technique perfected by the aircraft industry, where the ends of Z-sections are grasped by clamps and pulled down over a form of proper shape to make roof carlines. That this idea of bending taut metal is not restricted to thin sheets of aluminum is proven by its use for forming roof beams, side posts, and irregularly shaped stiffeners for railway passenger cars. JAMES CASSELL, ⊕, tool engineer for the car builders, said the new equipment reduced five handlings to two, as well as saved considerable material. This adds to the repertoire of forming methods observed in car shops, already leaning heavily on massive bending rolls and presses for hot-forming and flanging structural parts of irregular shapes . . . . . A most interesting series of refrigerator cars has recently been completed for the Canadian Pacific Railway — each one really a box within a car. Externally each one looks very like a modern box car with smooth

Temperature-controlled freight cars

steel sides and collision-proof ends. However, enclosed in this steel box is another one, completely wrapped around with 4 in. of blanketed insulation. The inner box is self-supporting, with welded floor, sides having rectangular flues made of copper-bearing steel sheet filling the spaces between U-beam posts; top beams strong enough to support meat-hook rails below and eight ice-brine tanks above. In turn this box is completely lined with wood. The plywood roof forms a plenum chamber under the steel car roof, cooled by the brine tanks — a reservoir for supplying cold air to the side-wall flues. Sides of the car and its floor are heavily slatted for rough wear, the floor being hinged along the sides so it can be tilted upward for cleaning. This wood floor also protects heater pipes for use when the cargo needs warmth rather than chill, in which event the heat is supplied by a charcoal burner swung under the car sills; the circulating medium is a solution of antifreeze. Pans, pipe and fittings coming in contact with the refrigerating brine are of steel, heavily galvanized, built according to best practices for ice-making plants; pH of solutions is checked periodically; thermometers outside the car show the inside temperatures at floor and roof. Thus, everything is quite comfortable for the traditional hog-on-ice.

Fundamental metallurgy

REVISITING Carnegie Institute of Technology after too long an absence, found the metallurgical department's laboratories in process of reconstruction and metallurgical research figuratively bursting its seams. Most of the latter is financed by Uncle Sam; for research at Carnegie is for the most part directed at *fundamentals*, matters which (unfortunately) industry is not so keenly interested in as to pay the bill. Diffusion in solid metal is the common denominator of many of the investigations — and well it may be, since it is basic to most of our "practical" heat treatments. Researches at Carnegie Institute have thrown much light on the hardening of steel, on the annealing of brass, on the carburizing and nitriding processes, on scaling and corrosion resistance. However, even yet, Director Robert Mehl says, there is no wholly clear understanding of the mechanism of diffusion — how an atom gets through an assemblage of other atoms, already closely packed . . . . . Considerable important work is now making use of radioactive isotopes or tracer elements — work that for convenience and safety is done in an off-campus building. For example Harry Schadel measures the vaporization of silver (radioactive silver from the Atomic Energy Commission) by heating the metal in a vacuum and condensing the evaporating atoms on a cold disk. Its amount may be as little as a millionth of a milligram if the temperature is much below silver's melting point, but it can readily be estimated by measuring the transferred radioactivity. Time, temperature, amount — these factors being varied, give data from which latent heat of vaporization can be accurately computed, a figure fundamental to thermodynamical activity and thus related to diffusion constants. Other lines of study, under general direction of Ernest Birchenall, use tracer elements to determine interchange of atoms between environment and metal surface (autophotographs made by laying the surface on sensitized paper show the progress of corrosion and its variation, point to point). Most difficult is the study of the iron oxide-hydroxide complex commonly called rust . . . . . New as these techniques are, substantial work continues on the old problems of steelmaking, on the properties of forging steels, and, oh yes, the glamour girl of metallurgy as well — nodular cast iron!

Wanted — students for metallurgical courses

MEMBERS of the American Society for Metals can do their Country and their profession a good turn by spreading the word to senior high-school boys that metallurgical engineering would be a wise course for them to choose in college. In the first place, a college education of any kind is worth the money it costs. Median salary of all male college graduates is $4689, whereas the median income of all American wage earners is $2840. In the second place, a course in engineering results in somewhat better jobs than other college graduates hold — the median salary of engineers is $4704. In the third place, metallurgists are much better paid than the general run of engineers — their median salary is $6368 (as revealed by an ⊕ survey of its members in 1949).

As to job opportunities, educators generally are worried about the current slump in engineering enrollment. For some years the G.I.'s have swarmed over the campus, but the freshman classes of 1949 will graduate only 19,000 engineers in 1953 — less than half the number of 1949 engineering graduates who were actually placed in jobs which utilize their engineering training. This slump in incoming students holds true for metallurgists as well. If there is anything left of the law of supply and demand, the embryo metallurgists graduating in the mid-50's will be able to pick their jobs at rather fancy entrance salaries. [P.S. — The ⊕ has a 100-page booklet, "Your Career in the Metallurgical Profession", that would be a good thing for you to put into the hands of a smart high-schooler. Also a disk — a 30-min. dramatized recording.] ⊕

Tumbling for Low-Cost Finishing

By Adolph Bregman
Consulting Editor for Metal Progress
Consulting Engineer
New York City

In the past few years rapid advances have been made in polishing and finishing metal products by tumbling. As a result, this process is now becoming more and more widely accepted for large-scale, low-cost finishing operations. However, in Mr. Bregman's opinion, it is still insufficiently explored for breadth of applicability.

TUMBLE FINISHING consists of rolling the work in a tumbling barrel, with a cutting or non-cutting compound, a rolling medium or carrier, and a fluid lubricant (often simply water). Small, simple, sturdy pieces may not require any rolling medium and such parts are termed "self-rolling".

The primary purpose of tumbling is to eliminate at least a large part of the most expensive operation in metal finishing — namely, hand or wheel polishing. However, it is not generally appreciated that tumbling can produce a luster close to the finish obtainable on a wheel. As one convinced proponent has stated, the art of tumbling has now progressed to the point where it is often difficult to tell the difference between tumbled and buffed parts.

General Principles — Tumbling takes place by the rotary movement of the load, which, in moving upward with the barrel, reaches the angle at which gravity overcomes the friction holding the mass together. At this point and above, the surface of the load slides toward the bottom of the barrel. According to one school of thought, most of the work is done at this sliding surface and much less, if any, within the mass. N. G. L. Russell believes, therefore, that an overloaded tumbler will subject the parts to added pressure but reduced sliding action, and consequently will produce less. Thus, a barrel filled to 1 in. below center will be finished before an overloaded barrel, and the quality of finish will be higher. It is better to underload the barrel and then gradually increase the load until the best results are obtained.

The quantity of sliding material and the depth or thickness of the slide increase with greater speed, up to the limit at which the work parts are tossed into space, eliminating friction. Of course, at still higher speeds, the load adheres to the periphery of the tumbler and all frictional action ceases.

An important factor is the barrel diameter. A 30-in. barrel, for example, provides a longer length of slide and consequently greater force of impingement at the bottom and greater output than a 15-in. barrel. However, fragile or soft parts which might be damaged by the force of impingement and the pressure of the deeper load should be processed in smaller barrels.

A different theory of the action within the barrel has been propounded by Hans Weiss. According to him, there are four distinct movements in the tumbler:

1. The relative motion of the seemingly stationary mass against the bottom wall of the barrel.
2. Adhesion to the barrel wall, raising the mass on the upgrade while gravity works in the opposite direction. When the top edge breaks over, a relatively small part of the load which is on top takes the long slide, while the balance settles down into the mass where it is subjected to short, very numerous rubbing actions between the parts and the rolling medium.
3. The slide across the diagonal of the barrel, which is the longest and most evident motion.
4. At the end of the slide, both parts and medium disappear into the mass. The settling, rubbing and churning actions are repeated.

It is Weiss's opinion that movements (1) and (3) play a minor part in the surface effects. It is not known how far the movements (2) and (4) extend toward the center of the mass and it is assumed that these two movements also are decreased in large-diameter barrels compared with smaller ones, but they may be increased in inten-

sity by other forces, one of which is pressure due to increased weight. Just as pressure is one of the vital factors in wheel grinding and polishing, it is also effective in tumbling. It may be applied in tumbling by the choice of larger barrels (and thus heavier weight of the total load) and by the use of heavy mediums. As evidenced by barrel burnishing with steel balls, the main factor in producing a highly polished surface is pressure under proper lubrication. Weiss cites his experience that heavier tumbling mediums shorten tumbling times, and that larger and heavier single pieces of tumbling medium speed up deburring action, to support his belief that pressure contributes much to accelerate cutting-down and surface-smoothing operations.

Equipment

Tumblers are of two types, horizontal closed and oblique open. Horizontal tumblers are most widely used because of their greater capacity. Oblique open tumblers are useful for small or odd-lot production or for self-tumbling. The barrels may be of steel shell construction with hard maple liners, easily replaced without dismantling the machine. Maple is the longest-wearing and most stain-resistant wood used for lining, but progress has been reported in rubber and other synthetic linings with the prospect of longer service life and effectiveness.

Tumblers may be cylindrical or polygonal in shape. The cylindrical barrel provides the smoothest movement while the polygonal barrel causes as many jerks during one revolution as the barrel has corners. These jerks may contribute to the churning action, but also increase the risk of hard hits. It is the opinion of Weiss that the force of the jerks decreases with an increasing number of corners and therefore, while the hexagonal barrel may be more rapid in deburring and cutting action, it is more likely to cause damage to the surface of the work than an octagonal or round barrel.

There should be no protruding parts inside the tumblers to catch and mar the work or retard operations. Their speed should be adjustable and conventional safety devices should be installed, such as vent cocks to release gas pressure and a thermostatic overload switch to prevent burning out in long runs or night work. The barrel may also be fitted with a tumbler which automatically separates the work from steel balls. Upon completion of a run, a perforated tray is set into the tumbler which is then given a partial revolution. The balls are automatically separated from the work and the finished parts can be discharged quickly from the machine.

The equipment most generally used is the horizontal wet barrel, completely enclosed and watertight. For dry de-finning, an open-meshed barrel may be used so that the burrs and fins drop through the meshes. In such barrels, the parts may be self-tumbled or rolled with balls and pegs. The sheet steel barrel, wood lined, is also suitable for dry finishing.

Sizes vary, of course, but a typical dry process barrel is about 30 in. in diameter and 36 in. long, operated at speeds from 12 to 28 r.p.m. For limited plant space, small parts and small production requirements, small machines are available, such as, for example, one using a chip mass of 25 lb. and processing as little as 5 lb. of parts.

Multiple tumbler units are available, entirely enclosed or with open-frame construction, with tumblers arranged vertically or horizontally. The picture on the next page shows a typical battery of tumbling barrels suited for mass finishing. Each tumbler should be adjustable to the speed required for its particular operation, such flexibility permitting different types of products and different operations to be carried on simultaneously. The unit may have built-in screens so that the abrasive is screened out automatically as the work is tumbled. Special features may include variable-speed drives and electric timers with push-button controls.

Accessory equipment consists of screens, hoist pans, separating tables, chip bins, hand, mechanized and magnetic separators, and water and oil tanks.

Oblique barrels have the advantage of low cost and easy loading and unloading. However, this type of barrel is limited largely to use with self-rolling parts since the work and the rolling medium tend to separate in such a way that large or light pieces float to the top and small, dense pieces remain at the bottom.

Carriers or Rolling Mediums

The carrier or rolling medium is the bulk material used to keep the parts from striking against each other, to improve the sliding action, to effect contact at points which cannot be reached without their aid and to distribute the abrasive material. A large number of mediums are in use: steel balls and other shapes, zinc alloy shapes; aluminum oxide, crushed and sized; wood shapes; vegetable ivory pieces; cinders, slags, abrasive-impregnated rubber and sand; all the way down to sawdust, leather, nut meats, ground corn cobs, cracked corn and dry ice.

Many of these materials are being replaced by quarried rock ("chip") which has been crushed, screened and tumbled to remove sharp edges. A

new form of chip is also available, a sharp abrasive, uniformly dispersed in a strong and relatively heavy bonding material.

A medium should be selected which will not clog blind holes or recesses in the work. If the holes are small and would fill up with sawdust and abrasive compound, shapes larger than the holes should be used; or they should be so small that they cannot jam. It is also essential that the medium be properly broken in before production runs, to eliminate scratches or dust which would harm the work. The medium should always be readily screenable from the work.

Metallic mediums are of two types, steel and zinc alloys. Hardened steel is obtainable in uniform sizes and shapes like balls, diagonals and balcones, highly polished. They are used exclusively for burnishing operations, only with noncutting compounds. Zinc alloys, in small diagonal forms and in flat disks, do excellent work in smoothing soft metals and in cutting and polishing hardened steel or stainless steel.

The effect of the medium depends on the character of the work. The larger and heavier the chips, for example, the greater the action on corners and exposed surfaces of the work, but the poorer the action on recessed and protected surfaces. Small or fine mediums will give better finishes.

Proportions of medium to work depend on the nature of the parts, tumbler speed, type of medium and the finish required. Sometimes even a 1-to-1 by volume suffices, although ratios generally range from 2 medium to 1 work, to 10 to 1. An extreme example of 21 to 1 for large heavy parts has been cited. The larger and heavier the part the higher the proportion of medium. Large-diameter or high-speed barrels require a greater proportion of medium than small or low-speed barrels.

For another example, a tumbling mixture of 1 part balls, 2 parts pegs and 2 parts work may be considered average. For small light parts the load may be ½ part balls, 1 part pegs, and 1 part work. Small steel stampings up to about 1 in. in the largest dimension may be run satisfactorily with a volume ratio of 1 to 1; steel stampings up to 3 in. long may require 3 to 1 for the medium-to-work ratio. Angle pieces, cupped pieces, and the like may require 8 to 1 or higher ratios. For burnishing, 1 part of work to 5 of steel shot is a common proportion.

The usual practice is to run the first load with a high medium-to-work ratio and then decrease the ratio gradually as far as consistent with acceptable results.

Steel burnishing mediums must be maintained free from rust or tarnish, mirror-bright and clean. They should be stored in a container with sufficient water and burnishing compound to keep all of the shot completely covered; or, if for long periods, they should be coated with a rust-preventive and kept covered. When shot is to be used again

This Battery of Tumbling Barrels Is Suited for Mass Finishing in Any Cycle to Attain Any Type of Tumbled Surface. (Courtesy Lupomatic Industries, Inc.)

after an inactive period, it should be cleaned in a good soak cleaner and rinsed thoroughly before being loaded into the tumbling barrel. Discoloration and rust should be removed with mild cleaners, but acid dips should be avoided.

Compounds

Barrel finishing compounds may be classed as "cutting" and "noncutting". They have four functions: *(a)* abrasion or cutting, *(b)* lubrication, *(c)* cleaning, and *(d)* prevention of corrosion or staining between operations. For work which is either self-tumbled or which uses a steel medium, these compounds consist of an abrasive, a high titer soap or an alkali, or mixtures of these three. With chips, soap may suffice, but with loose abrasives, alkalis and soapless cleaners with wetting agents may be used to advantage. For burnishing nonferrous metals, the alkalis should be quite mild (pH below 8 for aluminum) to avoid etching. Acidic chemicals may be employed to soften or dissolve any metallic scale present, to facilitate scale removal in tumbling.

There are many alkaline agents which will aid in rust prevention and provide detergent action, such as caustic soda, trisodium phosphate, tetrasodium pyrophosphate and washing soda. So, for example, in self-tumbling steel parts, a mixture of sharp silica and trisodium phosphate will be satisfactory if the ratio of water to abrasive is properly adjusted. After the abrasive run, the smoothed parts will have a gray, satin finish, but the clear metallic color may be restored by burnishing.

Freshly cut metal surfaces and fine metal chips may react with the water in the barrel to form oxides and liberate hydrogen. The compounds, therefore, should contain the necessary buffers and inhibitors to prevent corrosion or pitting of the metal. Obviously, different metals will require different compounds. Burnishing and "shine-rolling" compounds contain soaps, buffers, cleansers, emulsifiers, and the like, and are also specific.

Abrasives

The choice of abrasives, always critical for effective tumbling, can be determined only by experience. The type of abrasive and grain size depend not only on the cutting or smoothing action desired, but also on the material being tumbled. Sharp silica is often satisfactory but a harder, longer-lasting material is aluminum oxide grain.

Free abrasives added to chip loads will prevent flat, thin parts from sticking together or adhering to the sides of the barrel. They will also help to produce a surface better adapted for paint.

Methods of Operation

The most important element in tumbling is setting up properly for the specific parts to be treated. The considerations include the type of piece, the material, the shape, size and weight, the original surface, the finish desired, and production requirements. The cycle decided upon will determine the type and amount of compound, the type and amount of carrier, the type of barrel, the barrel speed and the relative proportions of work, abrasive and carrier in the barrel.

Tumbling may be done either wet or dry. Each method has advantages for special purposes.

Dry Tumbling

Dry tumbling may be divided into three broad classes: *(a)* cutting down, *(b)* smoothing or cleaning, and *(c)* polishing. Cutting down may be likened to greaseless polishing or finishing, on the wheel. It may be coarse for deburring, or so-called "normal" in character. It does not shape the part. Edges may be rounded and light burrs removed, but heavy fins or large imperfections are not removed except by prolonged dwells in the barrel.

Smoothing is equivalent to a cutdown with tripoli, tending to reduce surface imperfections. It also removes the residual abrasive from the previous cutting-down operation.

The polishing operation imparts a high-luster finish.

These three classes may be further subdivided to include "extra coarse" cutting, "light" cutting, and so on.

The above operations may be used singly or in combination. For example, die castings which have been carefully die trimmed may call for only a smoothing tumble, one of the commonest and quickest setups.

After dry tumbling, the parts have a film which should be removed by solvent degreasing if they are to be plated or lacquered.

Dry tumbling has a wide range of applicability, from heavy castings (which are self-tumbled) to the last finishing operations on small articles of light weight; even after electroplating, with the use of sawdust, leather scraps, felt pieces or a similar medium. Parts of intricate shapes, with grooves or recesses, present difficulties due to clogging of the medium, but all parts which present their full surface, whether flat or curved, to the action of artificial balls of ¼ to 1-in. diameter, can be dry tumbled. Such an operation will also remove the discoloration or tarnish resulting from a preceding wet process. *(Continued on p. 680)*

Oxidation of Molybdenum in Air at 1100 to 1600° F.

By B. Lustman
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Molybdenum (now available in high state of purity in ingot, sheet or rods) has many attractive properties, including high melting point, but one regrettable defect of rapid — even catastrophic — reaction with hot atmosphere. Dr. Lustman indicates the principles that will lead to a molybdenum-base alloy with a nonvolatile, impervious, refractory and protective scale.

A REVIEW of the literature disclosed no specific information on the rate of oxidation of molybdenum in air at atmospheric pressures. Information on this characteristic being necessary as a guide in alloy development, some preliminary tests were made with the results given herein.

To determine the rate of oxidation, samples of 30-gage sheet (0.0125 in. thick), 1 by 1⅛ in. in dimension, were cleaned by pickling in dilute nitric acid, and then heated in air in a muffle furnace at 1100, 1350, 1500, and 1600° F. for various lengths of time. The specimens were weighed before and after oxidation. To determine how much metal was converted to oxide, the scaled specimens were cathodically treated in dilute sulphuric acid at a current density of approximately 100 amperes per sq.ft., and again weighed after thus completely removing the adhering scale.

At 1100° F. the surface was coated with a loosely adherent scale consisting of an oxide which, at temperature, was yellow but became white on cooling to room temperature; this color change is characteristic of MoO_3. The oxide thickened in a direction perpendicular to each surface of the sheet so that, after heating, the specimens possessed a slab of oxide adhering to each surface. This behavior is similar to that shown by tungsten. At the higher temperatures, the sheet surface after oxidation was covered with a crystalline, steel-gray oxide, the size of the crystals increasing with increasing temperature. At 1500 and 1600° F., it was noted that the oxide was molten.

The behavior of molybdenum on oxidation is necessarily complex because of the nature of the oxide, MoO_3, which forms on heating in air. This oxide melts at a low temperature (1460° F.); furthermore it possesses a high vapor pressure below as well as above its melting point. Thus, at temperatures above the melting point of the oxide, the rate of attack of molybdenum by air will depend on the vapor pressure of the oxide, the amount of liquid oxide adhering to the surface, the degree of wetting of the surface by the oxide, the rate of gas flow past the specimen surface, and possibly other factors. At such high temperatures one would expect molybdenum to be rapidly attacked by air, since metals generally show only slight resistance to oxidation when protected only by a molten oxide. At temperatures *below* the melting point of the oxide, the oxidation rate will be controlled by the vapor pressure of the oxide and by the degree of protection afforded the metal by the solid scale.

It is known that tungsten, which chemically and physically resembles molybdenum closely, is not protected against further oxidation by the oxide which forms, and that the amount of oxidation therefore increases linearly with time. It will be shown in the following experimental results that molybdenum resembles tungsten in that the scale formed during oxidation in air at low temperatures is not protective.

Weights of the oxidized samples (Table I)

Table I — Weight Changes After Oxidation and Before Descaling
(+ is gain; — is loss; expressed in g. per sq.in. of surface)

1100° F.		1350° F.		1500° F.		1600° F.	
Time	Change	Time	Change	Time	Change	Time	Change
0.25 hr.	+0.003	0.5 hr.	+0.007	0.084 hr.	−0.213	0.04 hr.	−0.085
1.0	+0.006	1.1	+0.018	0.16	−0.455	0.16	−0.425
16.5	+0.062	2.1	−0.005	0.33	−0.890	0.50	−0.906
40	+0.140	3.0	−0.085				
66	+0.225						

show that at 1100° F. molybdenum increases in weight on oxidation proportionally to time. At 1350° F. there was first a weight gain and then a weight loss as more MoO_3 was vaporized. At the higher temperatures, the specimens lost weight continuously and rapidly. In Fig. 1 are shown the total losses in oxidized metal; the values plotted on the vertical scale are the differences in weights of the original specimens and those cathodically cleaned after heating. It will be noted that at 1100° F. the weight loss of molybdenum increases linearly with oxidation time. The figures in parentheses represent the percentage of the oxidized metal that remains behind on the oxidized sample *before* descaling. At 1100° F., almost all of the molybdenum converted to oxide remains on the metal surface as an adherent scale.

At 1350° F., the curve shows that the rate of loss of molybdenum seems to increase with time; furthermore, only about half of the oxidized molybdenum remains on the metal surface as scale, the rest being volatilized as oxide. At 1500 and 1600° F. the loss of weight by scaled samples is again constant (and very rapid). The apparent decrease in rate of attack at 1600° F. is probably illusory, resulting from a decrease in the surface area exposed to oxidation. At these temperatures only a small percentage of the molybdenum oxidized remains as scale, the percentage decreasing with increasing temperature and time.

In Fig. 2 are plotted, as a function of the inverse of absolute temperature, the logarithms of weight losses of molybdenum per hour at each temperature; such a plot generally yields a straight line when applied to oxidation data. It may be noted that at 1100 and at 1350° F., the rate of oxidation increases with temperature, whereas at 1500 and 1600° F. it seems independent of temperature.

These results are explicable when one considers that MoO_3, the major constituent resulting on oxidation, melts at 1460° F.; one would thus expect a discontinuity in the oxidation rate at such a temperature, since it is hardly to be expected that a molten oxide would afford the protection offered by a solid scale. At temperatures above the melting point of the oxide, the oxidation rate would probably be controlled less by chemical or diffusional rates than by mechanical factors such as wetting of the surface by the molten oxide or its rate of evaporation. Whether the oxidation rates follow, in fact, a course such as

(Continued on p. 674)

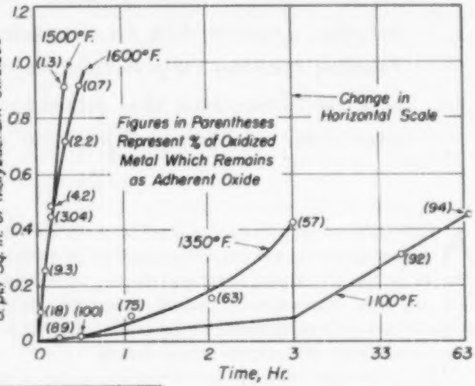

Fig. 1 (Above) — Amount of Molybdenum Oxidized at Various Temperatures and Times (Graphs) and Percentage of Oxidized Metal Which Remains as Adherent Oxide on the Sample (Figures in Parentheses)

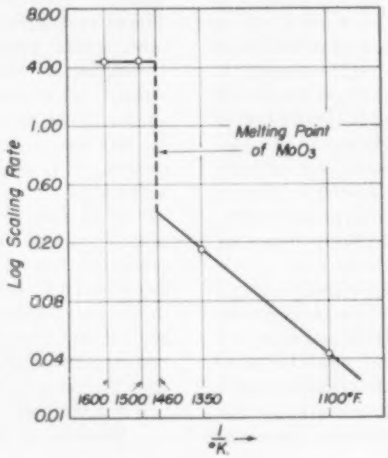

Fig. 2 (Left) — Tentative Plot Showing Variation in Oxidation Rate of Molybdenum in Air in the Temperature Range 1100 to 1600° F. Ordinates are logarithms of weight losses in grams per square inch per hour; abscissas are inverse of absolute temperatures

Alternative Iron Smelting Processes

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ONLY A FEW YEARS AGO anyone wishing to smelt iron ore in quantities of more than 5 tons or so a day, smelted the ore in a blast furnace or did not smelt it at all. This is no longer true. Several commercially proven processes will produce iron from ore profitably under certain very specific economic conditions. The task will be to define these economic conditions and to find out whether they exist where iron is needed.

We in Ontario Research Foundation have studied some 150 processes for producing iron from ores. Their most important feature from the Canadian viewpoint is the amount and quality of fuel needed, for reasons outlined in the article "Improving Blast Furnace Practice" in last month's *Metal Progress*. We have confined our detailed studies to commercially proven processes (operation for at least five years) because we could not find any others which showed enough promise to develop to the commercial stage, rather than spending the same sum of money to install a plant using a proven process.

The following discussion, then, is based on data obtained from commercial operations, with costs translated to Canadian costs as of 1948.

Location and Size

It must be emphasized that the most important factor in deciding whether or not an iron smelting industry should be established (or expanded) in a certain location is the size of the market and the area which can be reached at a competitive price.

For purely economic reasons a blast furnace smelting plant must be located close to the source of fuel and close to the market for its product, rather than close to the iron ore. Thus: In the most commonly used combination of equipment to produce steel, namely blast furnace and open-hearth furnace, about 0.85 tons of iron ore must be brought to the smelting furnaces in order to produce 0.5 tons of pig iron required to make 1 ton of *steel*. This ore costs about $6.25 at the furnace. To this iron must be added about 1.8 tons of coal, 0.5 tons of scrap steel, limestone and other materials which cost about $32.00. The freight charges on ore, which obtains low "commodity" rates, are much less than the freight charges on finished iron and steel, which are classed under "product" rates.

These factors make it evident that it is cheaper to bring the iron ore to the coal deposit (which generally has a heavy industrial center and steel market associated with it). This involves the minimum shipment of materials to the furnace and the minimum distance for shipment of product to the heavy industrial market.

For these reasons, then, it is generally true that it is more economical to ship ore from a new discovery to existing smelting centers than to establish new smelting centers near the ore deposits, *unless* high quality coking coal and a market are located near the new ore body.

This is not a very pleasant conclusion for countries such as Sweden, Venezuela and Canada where excellent deposits of iron ore exist at remote places. However, recent technical developments have demonstrated that it is possible, by reducing the amount of coke needed to smelt a ton of iron ore, to establish profitable *small-scale* smelting operations far from coal deposits. Certain other economic conditions must be satisfied in such a case. The most important is that the market to be satisfied must be so small that the installation of a blast furnace cannot be considered.

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*The second portion (slightly modified) of a paper entitled "Methods for Reducing the Amount and Quality of Coke Used in Smelting Iron Ore", read before the United Nations Scientific Conference on the Conservation and Utilization of Resources, held in the summer of 1949 at Lake Success, N. Y. The short ton of 2000 lb. is the unit used in this paper.

Table I — Cost of Blast Furnace Iron
Typical Production Costs per Short Ton of Basic Pig Iron; Canada, 1948
One furnace; 900 tons per day; 315,000 tons per year

Coke: 0.83 tons from own coke plant @ $10.00	$ 8.30	
Ore: 2.0 tons @ 50% Fe and $6.50 per ton	13.00	
Limestone: 0.43 tons @ $2.00 per ton	0.86	$22.16
Labor: 0.73 man-hr. at $1.20	0.88	
Repairs and maintenance	0.45	
Cooling water: 12,500 gal. @ 0.003¢ per gal.	0.37	
Casting, miscellaneous, and overhead	3.25	4.95
Production cost		$27.11
Gas credit		1.70
Net production cost		$25.41*

*This does not include fixed charges on an investment of about $28,000,000 or any profit for the operation.

Table II — Data on Small Blast Furnace at Domnarfvet, Sweden, 1947
Feed of Sintered Ore Plus Flux

Production	200 tons per day
Hearth diameter	9 ft. 14 in.
Working height	55 ft. 8 in.
Working volume	4850 cu.ft.
Tuyeres	8
Air blown	11,600 cu.ft. per min.*
Blast pressure	8.6 psi.
Coke per ton of basic iron	0.660 tons

*Normal temperature and pressure

Alternative Processes

The following brief descriptions only emphasize major differences:

Large Blast Furnace — Modern blast furnace installations are part of a highly integrated industry. In addition to producing pig iron, the furnace also produces slag, which may be used in making building blocks, cement and road materials. The gas from the top of the furnace is a very useful fuel in an integrated steel plant. The byproducts of the associated coke ovens are a profitable source of income. These facts are mentioned mainly to emphasize that the *replacement* of blast furnaces in any sizable number is almost out of the question at present because no other alternative process provides the many useful and necessary byproducts for use in an integrated industry. Costs are shown in Table I.

Small Blast Furnaces — In North America, metallurgists generally believe that a blast furnace must have a daily capacity of at least 900 tons to compete with existing installations. While this may be true in the United States (unless special care is taken with furnace operation) it is not necessarily true everywhere. The advantages to be gained in efficient operation of a small blast furnace are well illustrated by practices at Domnarfvet Steel Works in Sweden where efficient use is made of a charge that is principally sintered.

At this plant the charge to the small blast furnace is only sinter and coke, since all required fluxes and additions are mixed with the fine ore before sintering. These blast furnaces were only able to produce 100 tons of iron some years ago, and are now producing about 225 tons. This increase in daily capacity has been achieved mainly by increasing blast volume and careful attention to preparation of feed. Other data are contained

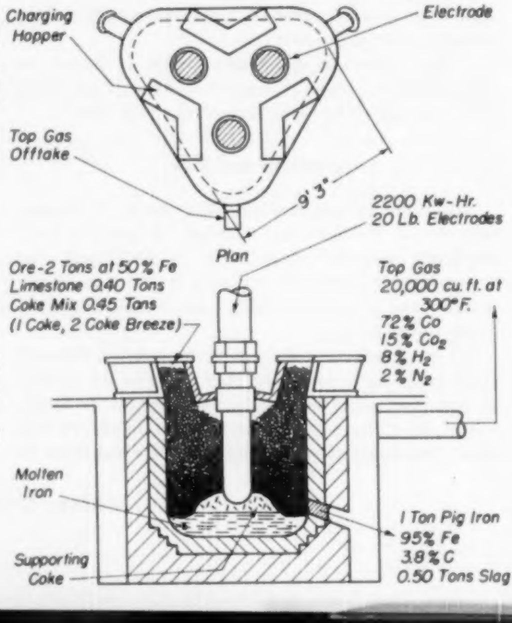
Table III — Cost of Electric Pig Iron
Typical production cost estimates per ton of basic pig iron (Canadian costs, 1948) in three Tysland-Hole 12,000-kva. electric smelting furnaces, producing 110 short tons per day. Plant capacity, 330 tons per day, or 125,000 tons per year.

Coke: 0.45 tons purchased coke mix*	$ 4.41	
Ore: 2.0 tons @ 50% Fe and $6.50	13.00	
Limestone: 0.40 tons @ $2.00 per ton	0.80	
Electrodes: 0.015 tons @ $120 per ton	1.80	
Power: 2250 kw-hr. at 0.3¢	6.75	$26.76
Labor: 1.7 man-hr. at $1.20	2.04	
Repairs and maintenance	0.85	
Cooling water: 10,000 gallons at 0.003¢	0.30	
Casting, overhead, and miscellaneous	3.40	6.59
Production cost		$33.35
Gas credit @ 25¢ per million Btu.		1.55
Net production cost		$31.80†

*Made of 0.15 tons of metallurgical coke @ $14.75 and 0.30 tons of coke fines @ $7.35 per ton

†This does not include fixed charges on an investment of about $9,750,000, or any profit for the operation.

Fig. 1 — Sketch of Tysland-Hole Electric Furnace (Low-Shaft) for Smelting Iron Ore. Quantities are for production of one ton (2000 lb.) of basic pig iron



in Table II. Coke consumption per ton of pig iron (0.660 tons) is remarkably low. Evidently, a small blast furnace can be efficient and profitable in the right location.

Electric Smelting — The Tysland-Hole furnace (Fig. 1) is at present the most satisfactory furnace for electric smelting of iron ore. Coke fuel is replaced by electrical energy. The quantity of gas escaping is only about one sixth. This gas reduces and preheats the charge, but since the volume is so much less, its work is completed after only a very short travel up the shaft. There is, therefore, no necessity for a high shaft, and the pressure on the coke is only a fraction of that in a blast furnace. For this reason, low strength coke may be used in the low shaft electric smelting furnace.

Since the volume of gas is so small, it is not so important to have a large percentage of voids in the charge, and a much greater percentage of fine coke or fine ore may be used.

The operation is a desirable type of load for an electrical supply system, and the furnaces may be run as low as 65% of rated capacity without difficulty, thereby affording an opportunity to take advantage of seasonal or off-peak excess power. The product is molten pig iron, as with the blast furnace. There is evidence that it is easier to make a standard pig iron with poor raw materials than in the blast furnace. Table III gives comparative costs, based on Canadian conditions in 1948.

Sponge Iron Process — In the very efficient Wiberg-Soderfors process, iron ore is reduced to metallic iron without ever being melted. The temperature in the furnace is about 1850° F. so the refractories are not required to withstand such extremes of temperature as in other processes. No coke or flux is introduced into the furnace. All the impurities present in the ore, with the exception of sulphur, occur in the final product, but no further impurities are introduced from coke, as they are in processes producing molten iron.

The method of recycling the spent reducing gas and regenerating it in an electrically heated carburetor accounts for the excellent efficiency of the process. Best results are obtained with a rich, easily reducible ore. A diagram of the equipment is shown in Fig. 2 and a cost estimate is presented in Table IV.

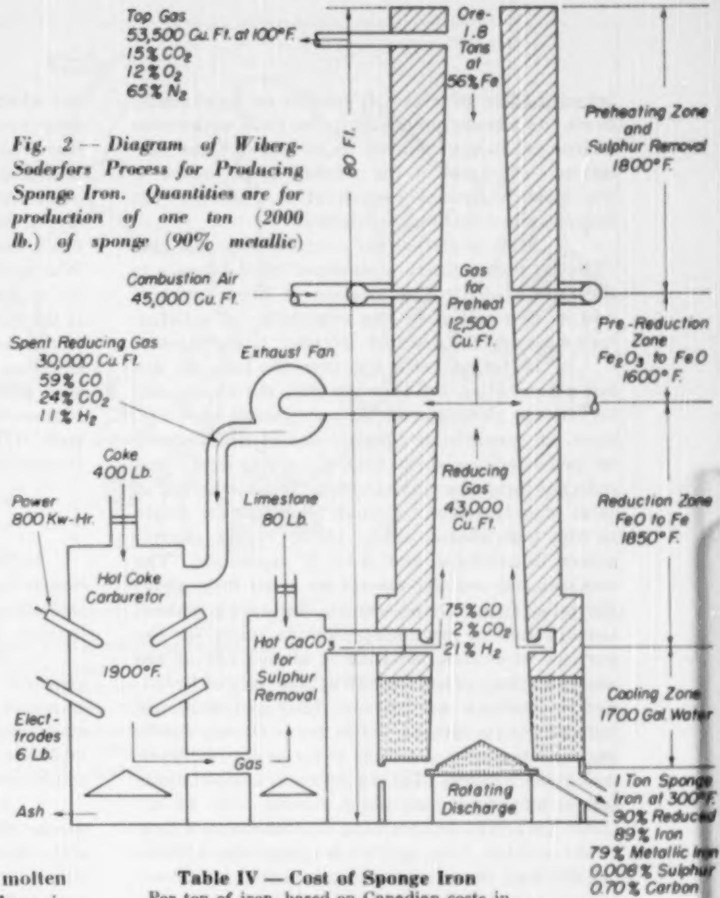


Fig. 2 — Diagram of Wiberg-Soderfors Process for Producing Sponge Iron. Quantities are for production of one ton (2000 lb.) of sponge (90% metallic)

Table IV — Cost of Sponge Iron

Per ton of iron, based on Canadian costs in 1948, for two Wiberg-Soderfors furnaces, each producing 73 tons per day of 90% reduced sponge iron. Capacity of plant, 145 tons per day or 50,000 tons per year

Coke: 0.22 tons purchased coke @ $14.75	$ 3.24	
Ore*: 1.8 tons @ 56% Fe and $10.25	18.45	
Limestone: 0.04 tons @ $2.00 per ton	0.08	
Electrodes: 0.003 tons @ $120 per ton	0.36	
Power: 800 kw-hr. at 0.3¢	2.40	$24.53
Labor: 1.9 man-hr. at $1.20	2.28	
Repairs and maintenance	1.50	
Cooling water: 2000 gallons at 0.003¢	0.06	
Overhead and miscellaneous	3.00	$ 6.84
Net production cost		$31.37†

*Selected lump ore from Steep Rock deposit.

†This does not include fixed charges on an investment of about $3,000,000 or any profit for the operation.

Choice of Processes

Comparative investment costs are shown in Table V for processes mentioned so far.

In studying the possibility of establishing an iron smelting industry in any locality, the choice

between these processes is limited by local conditions. As already pointed out, the local occurrence of iron ore is *not* the most important of these conditions — the size of the market to be served is the most important consideration. Market size imposes the following restrictions:

1. With a market for over 600 tons per day (225,000 tons a year) a standard blast furnace is the only choice. The location of blast furnaces will be determined by the availability of satisfactory coke and the distance (freight) to the market.

2. If the market is less than 600 tons per day but greater than 400 tons per day, the choice will be between electric smelting and a small blast furnace. A small blast furnace should use sintered or pelletized-and-sized feed to obtain costs and coke consumption comparable to those achieved in large blast furnaces. A small blast furnace would be the best choice unless cheap excess electric power is available and coke is expensive. The smelting site usually cannot be more than about 200 miles from a hydroelectric generating station. Construction of generating stations solely for the purpose of electric smelting is almost out of the question, since present construction costs of hydroelectric stations are between $160 and $250 per horsepower (in Canada). The use of electric smelting is particularly attractive if seasonal or off-peak power can be used. This is shown in computations for a hypothetical plant having one 55-ton (6000-kw.) furnace operating continuously on firm power costing 0.3¢ per kw-hr., and one 110-ton (12,000-kw.) furnace standing by, ready to operate for any period daily on off-peak power costing 0.1¢ per kw-hr. Pig iron would cost about $31.50 per ton when the stand-by did not operate at all; costs drop more or less proportionately as the 110-ton furnace operates longer and longer periods, finally reaching about $28.50 per ton in flood seasons when off-peak power is available 24 hr. a day.

3. If the market is less than 400 tons per day, the choice is between electric smelting and the Wiberg-Soderfors sponge iron process. If electricity is particularly cheap and plentiful, if pig iron is the product desired for foundry use as well as steelmaking, and if the rich fuel gas from electric smelting furnaces can be used in the rest of the steel plant, electric smelting is the better choice. If there is no use for a rich fuel gas and particularly if high quality steels are to be made, the Wiberg-Soderfors method is an attractive process.

Effect of Marketing Conditions

In considering the choice of process in a particular country or region and keeping the above limitations in mind with respect to *size* of the market, the following rules are helpful:

1. In a heavily industrialized region with plentiful supplies of high-grade coking coal, the standard blast furnace combined with openhearth steelmaking furnaces (which consume steel scrap available in an industrialized country) is the best combination for making ordinary steels.

2. In an industrialized region with a small market for steel and with satisfactory coking coal, and where electric power is expensive, a small, efficiently run blast furnace is the most interesting process to study.

3. In a region with plentiful cheap electric power and no coking coal, electric smelting may be practical to satisfy small markets.

4. In a region having no heavy industry the combination of the Wiberg-Soderfors process with electric steelmaking furnaces may form the basis for a very small steel industry. No purchased scrap need then be added to the charge. This is an important factor in countries which do not have any heavy industry.

5. In a country where a small blast furnace or electric smelting may appear profitable, the choice of steelmaking equipment will be largely determined by the amount of scrap available in the country. If the region is not highly

Table V — Comparative Investments*

Item	Pig Iron From Standard Blast Furnaces	Pig Iron From Tysland-Hole Electric Furnace	Sponge Iron by Wiberg-Soderfors Process
Number of furnaces in plant	1	3	2
Total yearly output, tons	315,000	125,000	50,000
Plant costs†			
Furnaces and auxiliaries	$12,000,000	$5,000,000	$1,300,000
Buildings	2,000,000	1,000,000	400,000
Ore handling equipment‡	2,000,000	1,000,000	300,000
Coke ovens	6,000,000	—	—
Working capital (six months)	4,000,000	2,000,000	750,000
Engineering and contingencies	2,000,000	750,000	250,000
Total investment	$28,000,000	$9,750,000	$3,000,000
Investment per ton-year	$88	$78	$60
Same without coke ovens	$70	$78	$60

*These costs are not meant to be exact and do not apply to any particular location. They are representative costs for Canada in 1948 and can only be used for purposes of comparison.

†Costs include stockpiling and materials handling equipment, office and plant buildings, power lines, sewers, boiler houses and steam lines, foundations and all other necessary auxiliaries on a new site.

‡Includes equipment for handling other solid materials, as well. Blast furnace requires docks and ore bridges. Docks are not provided for in estimates for Tysland-Hole and Wiberg-Soderfors furnaces.

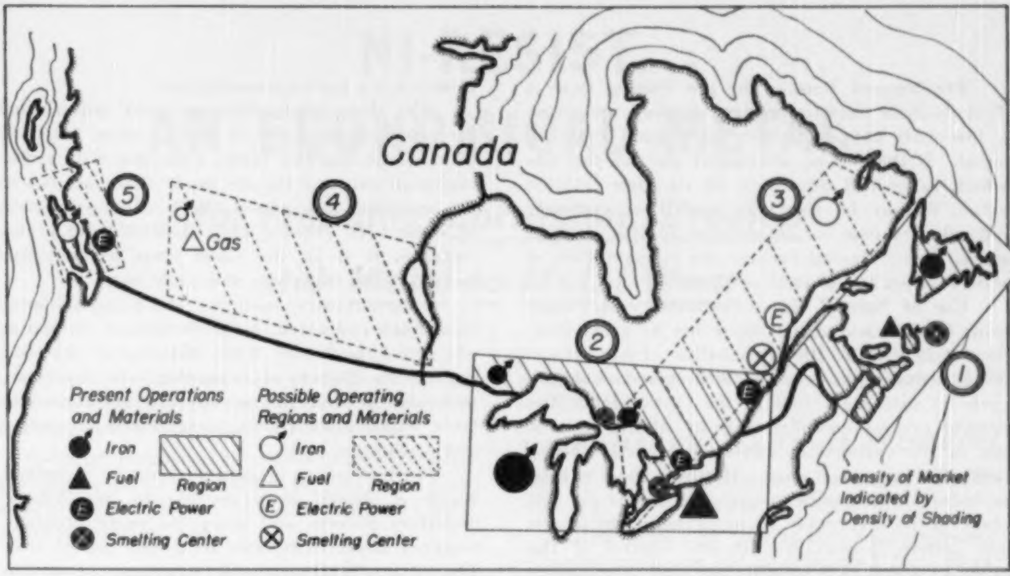


Fig. 3 — Sketch Map Showing Where Alternative Processes Have Best Chance Under Present Conditions in Canada

Processes worth studying in detail:

Region 1—Blast furnace
Region 2—Blast furnace
Region 3—Electric smelting (also sponge iron for high-quality melting stock)
Region 4—Modified Wiberg process (?)
Region 5—Electric smelting

industrialized there may not be sufficient scrap to operate openhearth furnaces efficiently. Bessemer converters then can produce steel from molten pig iron.

6. The fact that the Wiberg-Soderfors sponge iron process reduces the ore to metallic iron without melting it eliminates the possibility of contamination of very pure ore with impurities from the coke. The high purity of some sponge iron makes the process applicable in some very special situations. If a very pure, easily reduced ore is available and high-quality steel is to be produced, some sponge-iron capacity may be justified — even in the center of a highly industrialized area where blast furnaces are operating profitably.

Choice of Processes for Canada

It may be of interest to show how the above rules apply in Canada. In studying the suitability of various processes it is necessary to divide the country into distinct zones determined by the availability of metallurgical coke, of excess electric power and of iron ore. The accompanying map (Fig. 3) illustrates the entirely different conditions which exist in different regions.

Other Special Processes

Krupp-Renn Process — The Krupp-Renn rotary kiln has been tried in many countries and has been successful in producing iron from high-silica ores which cannot be treated profitably by other methods. The output per unit is very small and the operating difficulties make its wider application very doubtful. (See *Metal Progress*, April 1950, p. 510.)

Brick kiln process has been studied exhaustively in the United States as a possible method for supplying a substitute melting stock when steel scrap is scarce or very expensive. We have followed up and extended this work done by the United States Bureau of Mines. It appears that it is a useful method of suddenly increasing the supply of steel melting stock in a country where modern brickmaking kilns are plentiful.

Fine ore is charged into containers or saggers along with fine coke dust. Charging methods have been developed so that the ore and coke may be laid in alternate horizontal or vertical layers. Methods have also been developed for automatically charging ore columns into the containers through steel tubes which are then withdrawn from the container.

Labor requirements are relatively high and the production costs are higher than for other methods of producing melting stock, although the consumption of coke is low and waste fine coke may be used.

This process is regarded purely as an emergency measure, or possibly as a source of extra income for brick companies with idle kilns.

Pre-Reduced Feed — The gas issuing from a Tysland-Hole electric smelting furnace and from a low-shaft oxygen furnace is a good reducing agent. If there is no alternative use for this gas which takes full advantage of its high calorific value, it may be used for partial or complete reduction of iron ore in suitable auxiliary equipment, thus reducing further the consumption of solid fuel per ton of steel produced.

Use of Natural Gas — Preliminary investigations have indicated that there are no great technical difficulties to the introduction of natural gas or oil refinery gas into the Wiberg-Soderfors gas cycle to save solid fuel in the carburetor. The present process, modified only by adding suitable gas to the carburetor, can operate with only a negligible amount of coke. However there will be no reduction in electric power. The added gas will crack in the carburetor, forming mainly hydrogen and carbon monoxide. Proper control of the quantity added of a suitable gas, and of temperature, can give the same gas analysis entering the furnace shaft as used in the conventional process.

Alternatively, the hot reducing gas may be manufactured by a suitable "synthesis gas" process. This method will probably prove slightly more expensive than the just-mentioned modification, but it does not need large amounts of power.

The commercial proving of these alternative modifications of the Wiberg-Soderfors process will be of great value to countries possessing rich iron ore, large reserves of natural gas or oil, and a small market for steel. If first-class natural gas is available for less than 8¢ per 1000 cu.ft. a detailed economic study is certainly worth while.

Other Direct Reduction Processes — We have found Table VI very useful in assessing new proposals for direct reduction. There is always the possibility that a new process will fit a given set of conditions of available fuel, raw materials, and required output better than the present commercially proven processes. Examining every proposal in detail is a time-consuming job.

Table VI — Energy Requirements

Approximate net consumption, in B.t.u., for different processes per short ton of total iron in the product (with credits for recovered heat in gases and products)

Blast furnace	11,000,000 B.t.u.
Tysland-Hole electric smelting	11,200,000
Wiberg-Soderfors sponge iron	8,200,000
Brick kiln sponge iron	14,500,000

Editor's Footnote — In Greenwood's "Steel and Iron" (1884) we find that the Catalan forge — the "commercial" source of civilization's iron for about 1000 years — requires 10¾ cwt. of charcoal to produce 3 cwt. of iron. This ancient direct-iron process, which operated in the U.S.A. as late as 1900, therefore required 100,000,000 B.t.u. per ton of iron!

The theoretical minimum heat requirement for producing one ton of iron is about 6,250,000 B.t.u. This quantity varies somewhat with reducing conditions and the ore used. This fact is useful because if a proposed direct reduction process is stated to require only 2,000,000 B.t.u., for instance, it is in the same class as perpetual motion. The study can stop right there.

A careful estimate of the total B.t.u. consumption, when compared to the theoretical minimum, will give a rough idea of the efficiency of any process and its chances of competing with that commercially proven process in the accompanying table which corresponds most closely in output and production costs.

For instance, a process we recently examined, which is similar in principle to the Wiberg-Soderfors process and gives the same products, requires about 35,000,000 B.t.u. per ton of iron. This obviously eliminates it from competition. The Wiberg-Soderfors process, which is commercially proven, should be used instead, unless the new process has some enormous advantage in being able to use a very cheap fuel which the Wiberg-Soderfors process cannot use, and the labor and equipment costs are so low that the production costs for the new process are much below the Wiberg-Soderfors costs.

Conclusions

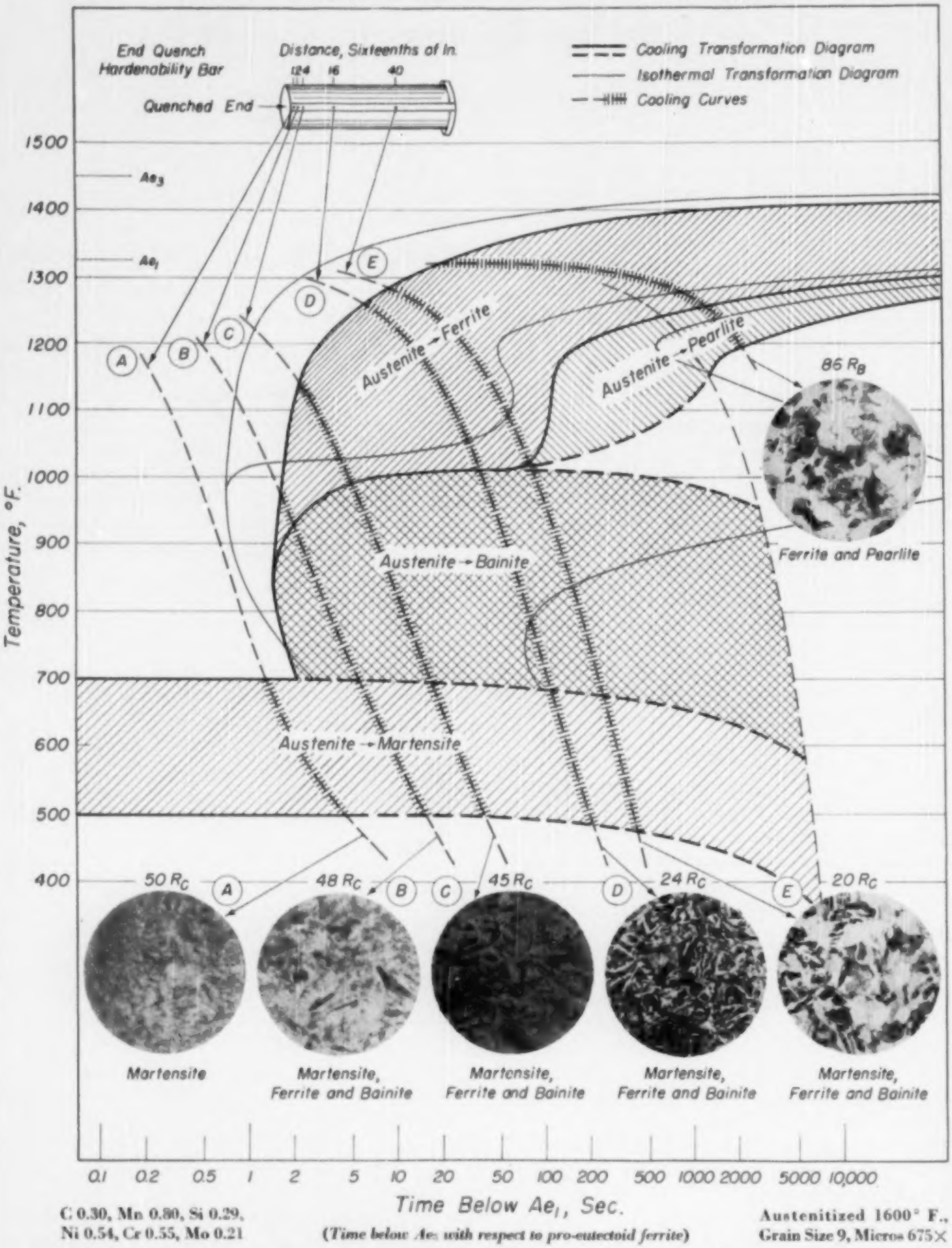
As noted in the article about blast furnace operations last month, no major savings in coke consumption appear likely in the near future except by modifying its operating techniques, and a table was given showing that this would probably follow an increase in top pressure alone, or in combination with an increase in blast volume or oxygen-enriched blast. There is a prospect of effecting considerable saving in the consumption of high-grade coking coal by smelting iron ore in low-shaft oxygen furnaces. In regions where oxygen can be produced for less than $5.00 per ton, this may be profitable.

It further appears that no alternative process can compete with blast furnace smelting in a region containing heavy industry. If the ore or coking coal is not nearby, it is more economical to ship these raw materials to the industrial center than to smelt at some distant ore body. Minor savings may be made, particularly in establishing new iron smelting centers, by choosing alternative processes which do not require as much coke or as high a grade of coke as the blast furnace. These processes are only profitable when used on a small scale in certain special conditions.

Transformation of 8630 Steel

Continuous Cooling and Isothermal Transformation Correlated With End Quench Hardenability Specimen

By R. A. Grange, J. F. Boyce and V. G. Peck, U. S. Steel Corp.



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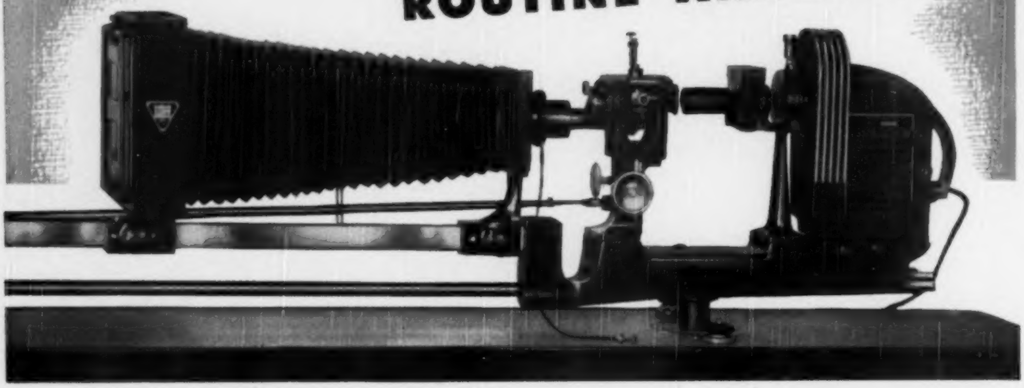

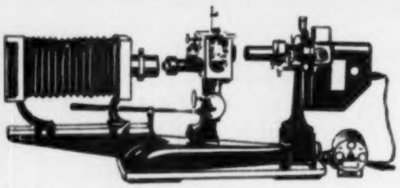

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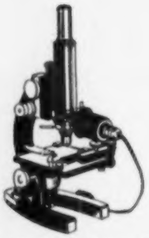

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The Transformation of Austenite in 8630 Steel

By R. A. Grange, J. F. Boyce and V. G. Peck
Research Laboratory
U. S. Steel Corp.
Kearny, N. J.

Modern heat treating is based on accurate knowledge of the transformation characteristics and microstructure of standard steels. The authors summarize such information for 8630, one of the most popular low-alloy grades. Included are isothermal and continuous cooling diagrams, hardness and microstructural variations along the end quenched hardenability bar, data on the martensite range, and optical and electron micrographs.

THE nickel-chromium-molybdenum steel designated S.A.E.-A.I.S.I. 8630 was introduced during the recent war as one of the National Emergency (N.E.) steels. Because of its relatively high hardenability per unit of cost, 8630 became popular and continues to be used extensively. In the work described here the transformation of austenite in a typical commercial heat of 8630 was investigated with results which should be of particular interest to those concerned with the practical heat treatment of this grade of steel.

For studying the various aspects of austenite transformation, specimens were prepared from a bar, 1¾ in. diameter, from an openhearth heat deoxidized with silicon and aluminum. The chemical composition, which is well within the limits specified for 8630 steel, follows:

C	Mn	Si	Ni	Cr	Mo
0.30	0.80	0.29	0.54	0.55	0.21

Before any specimens were prepared, the hot rolled bar was normalized from 1650° F.

The isothermal transformation diagram (hereinafter abbreviated "I-T diagram") was determined by heat treating and examining metallographically more than 100 small specimens. The metallographic data were supplemented by dilatometric measurements, which were especially helpful in determining the time required for complete transformation in the vicinity of 600° F.; in this range the appearance of the isothermal product (low-temperature bainite) is similar to that of martensite formed between 700 and 600° F., and it is difficult to observe the progress of isothermal transformation by microscopic examination.

Ae_1 and Ae_3 Temperatures — In measuring these temperatures, a small specimen, initially martensitic, was heated at a carefully controlled temperature for a period of 4 hr. and then quenched in brine; subsequent examination of the microstructure revealed whether the specimen had been heated above, within, or below the temperature range between Ae_1 and Ae_3. A sufficient number of different temperatures were investigated in this way to establish Ae_1 at 1330° F. and Ae_3 at 1450° F. Thus, 8630 steel must be heated above 1450° F. (well above unless the heating is unusually prolonged) to austenitize the steel completely. If heated between 1450 and 1330° F., the structure consists of ferrite, probably some carbide toward the lower limit of this range if the time of heating is relatively short, and austenite, the latter becoming martensite on quenching to room temperature. Below 1330° F., austenite transforms in the time indicated by the I-T diagram. In tempering, 1330° F. must not be exceeded if formation of any austenite is undesirable.

Isothermal Transformation

Figure 1 is the I-T diagram, which summarizes measurements of isothermal transformation for this sample of 8630 steel after austenitizing at 1600° F.* After holding each small specimen at this temperature for 15 min., the austenite grain size was No. 9. Progress of transformation was measured at each of 13 temperature levels in the range 1400 to 600° F. Hardness values in the right margin of Fig. 1 represent not only the measured hardness after transformation was just complete, but also indicate by their position the temperature levels investigated. The curve representing the beginning of transformation was based on the appearance of the first definite trace (about 0.1%) of transformation product, and the ending curve on the time at which the last trace of martensite (austenite prior to quenching) had just disappeared. The centrally located dashed line indicates the time for 50% transformation.

This diagram indicates that 8630 steel can be annealed in the shortest time by transforming at 1200° F. The fact that transformation begins in less than 1 sec. in the vicinity of 1000° F. implies relatively low hardenability, on the basis of a completely martensitic structure, for this steel as compared with many other popular low-alloy steels. Despite this rapid initiation of transformation at 1000° F., several days are required for completion; this behavior is characteristic of many steels containing an appreciable percentage of chromium and molybdenum and is associated with a two-stage reaction.

Microstructures after isothermal transformation is just complete are shown in Fig. 2, for intervals of 100° F. in the range 1300 to 600° F. For each temperature an optical micrograph at 1600 × is compared with an adjacent micrograph of the same specimen taken with the electron microscope at a magnification of 10,000.† In general, the structure revealed in the electron microscope pictures resembles the corresponding optical microscope image, but the electron microscope has much higher resolving power and hence reveals some structural detail in optically unresolved aggregates formed at the intermediate and lower temperature levels. In the electron micrographs the random small particles which appear in the ferrite matrix are of unknown significance; they may be artificial detail not actually present in the microstructure but introduced in the rather involved and indirect technique used to produce the image with the electron microscope.

At 1300 and 1200° F. the structure consists of ferrite and pearlite; the pearlite is resolved in the optical micrograph and appears very coarse in the electron micrographs. The pearlite at 1100° F. is only partly resolved in the optical micrograph. At 1000° F., transformation began with formation of

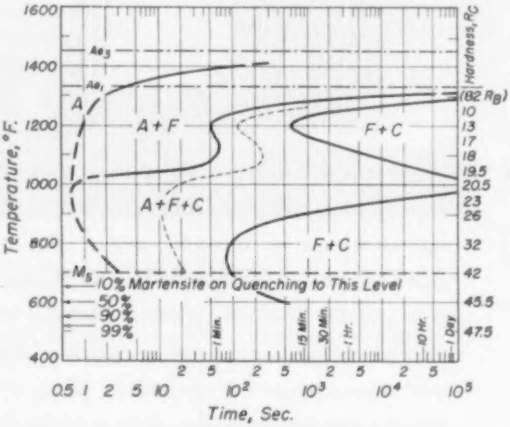


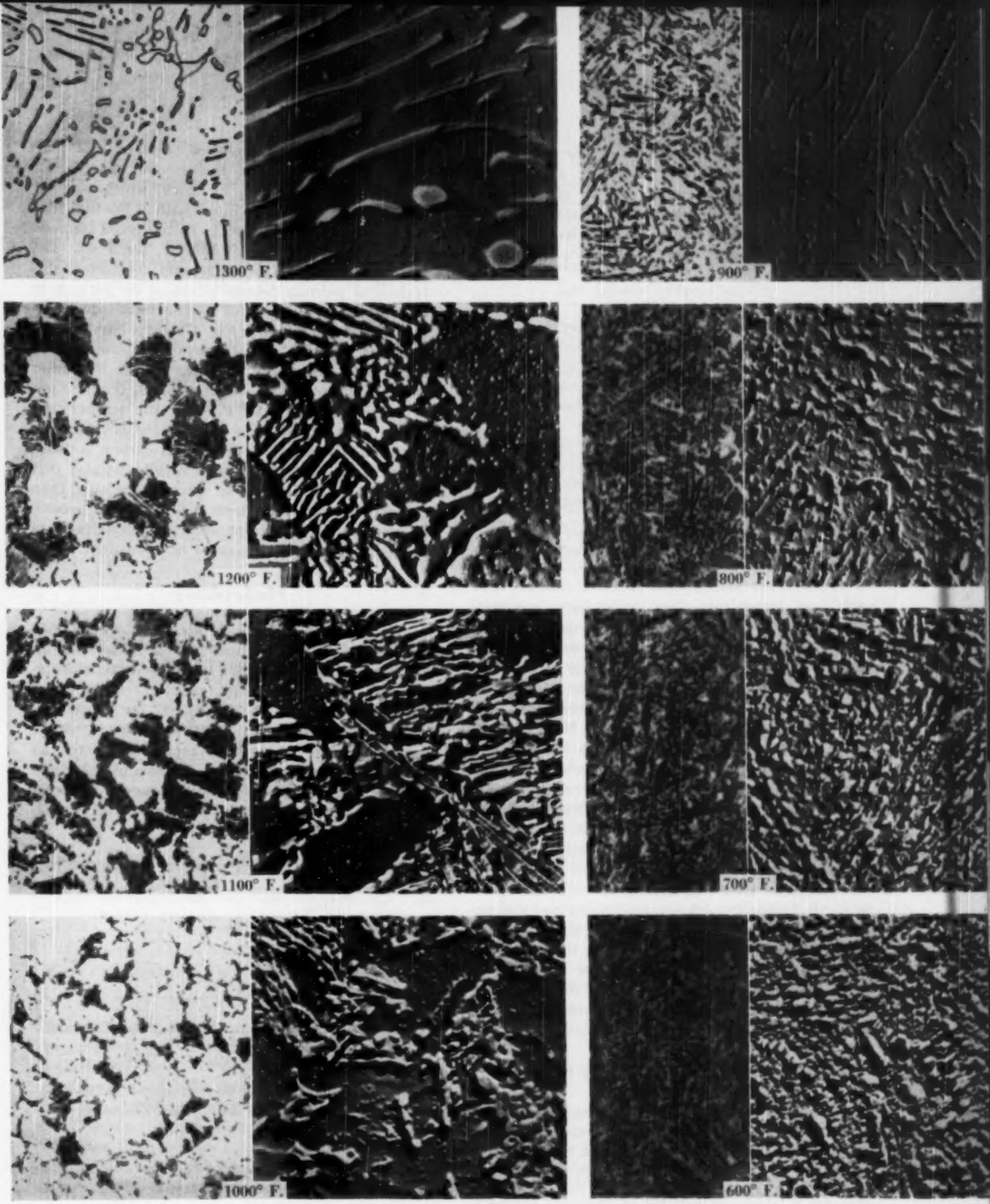
Fig. 1 — Isothermal Transformation Diagram for an 8630 Steel Austenitized at 1600° F. Grain size 9

acicular ferrite containing an occasional dot-like carbide; this reaction proceeded rapidly until about two thirds of the austenite had transformed, whereupon a dark etching, optically unresolved aggregate began to form. The structure of this second-stage product is particularly interesting and is shown by the electron micrograph to be a continuation of the pearlitic sequence of aggregates, although, of course, finer than pearlite formed at higher temperature. The rapid beginning and extremely slow ending of transformation in the vicinity of 1000° F. is thus explained by transformation to two different types of transformation product, the first of which seems to be a "transition" structure between pro-eutectoid ferrite and bainite and the second, a continuation of the pearlitic aggregates.

The structure of 8630 steel after complete transformation at 900° F. is difficult to classify, but is probably best regarded as a high-temperature form of bainite in which carbides are not uniformly dispersed in the ferrite matrix. The

*An I-T diagram for 8630 steel has been determined previously by others and appears in a pamphlet published in 1943 by the International Nickel Co. entitled "Isothermal Transformation Diagrams for Some Constructional Alloy and Carbon Steels", p. 27.

†Electron micrographs were prepared by making a two-step replica (polyvinyl alcohol and collodion) and shadow casting with chromium. The structure was photographed at a magnification of 5000 × and subsequently enlarged to 10,000 ×.



Optical Micrographs. 1600× Electron Micrographs. 10,000× 1600× 10,000×

Fig. 2 — Structure of 8630 Steel After Completion of Isothermal Transformation at Temperatures Indicated. Picral etch

greatest change in appearance of the microstructure occurs in the vicinity of 900° F., and the 900° structure seems somewhat out of place in the series. The remaining three micrographs, covering the range 800 to 600° F., are familiar bainitic structures. During quenching to 600° F., about half

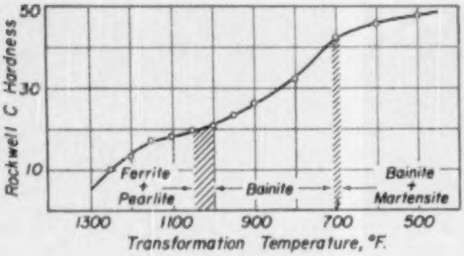


Fig. 3 — Hardness After Isothermal Transformation Is Just Completed in 8630 Steel

the austenite transforms to martensite, which is tempered and becomes dark-etching while the rest of the austenite is transforming to bainite at 600° F. These two structures cannot be differentiated in either of the micrographs shown for 600° F. The electron micrographs reveal that with decreasing temperature in the range 800 to 600° F. the carbides seem to fill the ferrite matrix more completely; presumably, the carbides became more uniformly dispersed the lower the transformation temperature, although shadow casting the replica for the electron microscope may have considerably distorted the true size, shape and relative proportion of carbides.

Hardness after transformation is just complete is plotted against each corresponding transformation temperature in Fig. 3. Although hardness increases as temperature decreases, the change is not uniform; inflections occur in the curve where the structure changes from pearlite and ferrite to bainite (1000° F.), and again where it changes from bainite to bainite plus martensite (700° F.).

Temperature Range of Martensite Formation

The lower portion of the I-T diagram (Fig. 1) presents data regarding the proportion of martensite formed on quenching to several temperatures in the range 700 to 520° F. These data cannot be obtained from measurements of isothermal transformation since martensite forms on cooling rather than on holding at a constant temperature. Consequently, it was necessary to make a special set of measurements which are summarized graphically in Fig. 4. Each plotted point on this chart represents the result of microscopic examination of a small specimen, $\frac{1}{32}$ in. thick, which was *(a)* quenched from 1600° F. into a bath at the indicated temperature for 2 to 3 sec., *(b)* tempered immediately, without cooling, at 1300° F. for 3 sec., and *(c)* quenched in brine. Properly conducted, this technique permits determination of the percentage of martensite formed during the initial quench.*

The data plotted in Fig. 4 yield a curve whose shape is similar to that previously observed for martensite formation in other steels of similar carbon content. For 8630 steel the M_s temperature is relatively high (700° F.) and the temperature range from M_s to 99% martensite is relatively narrow; this is due largely to its carbon content, which is only 0.30%. These results suggest that 8630 is less susceptible to quench cracking than competitive low-alloy steels having their martensite ranges at lower temperature, and less likely to retain any significant amount of austenite.

Hardenability

Like all other grades of hardenable steel, 8630 varies somewhat from heat to heat in hardenability and also in the rate of isothermal transformation, which is largely attributable to variation in composition within the limits set for the grade. Thus, an I-T diagram determined for a single sample of 8630 can no more represent exactly the isothermal transformation of all heats of 8630 than a single end quench hardenability curve represents the precise hardenability of all heats of this grade.

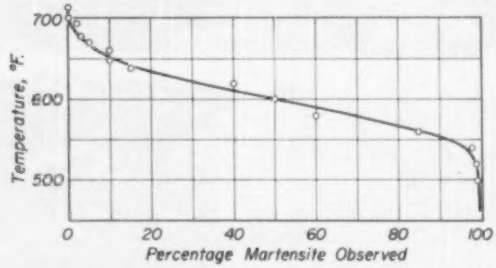


*Fig. 4 — Metallographic Observations of Martensite in 8630 Steel Quenched to Various Temperatures**

It is of interest, therefore, to compare our particular sample with other 8630 heats. This can be done more conveniently for hardenability curves

*For specimens containing more than 95% martensite, X-ray methods show consistently greater amounts of retained austenite than microscopic methods.

than for I-T diagrams, because the latter are not available and a large number of measurements would be necessary to obtain enough of them to represent variations among many heats of 8630.

The end quench hardenability curve of our sample is shown in Fig. 5, in comparison with the current hardenability band for 8630H steel. The hardenability of our sample of 8630 is on the low side of the band; the reason for this is not entirely clear, as the composition of our sample is near the middle of the range for 8630, but may be explained in part by the fine austenite grain size (No. 9) of our sample. If I-T diagrams were to be determined for many 8630 heats, it is probable that the one for our sample (Fig. 1) would indicate

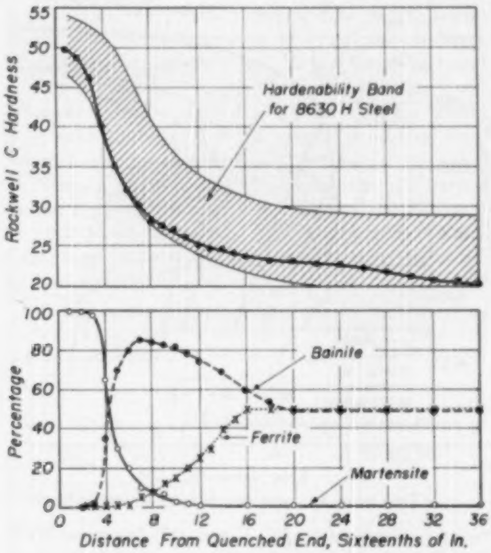


Fig. 5 — Hardness and Microstructure Along an End Quenched Hardenability Bar of 8630

somewhat faster transformation than most others; nevertheless, the shape of our diagram and the implications to be drawn from it are reasonably representative of 8630 steel in general.

Microstructures along the end quenched hardenability bar are of interest because the transformation products are formed during continuous cooling at a series of cooling velocities, and the structures may be considered as analogous to a mixture of various isothermal products. The lower chart of Fig. 5 summarizes our examination of the microstructure at the various locations in the end quenched bar; an attempt has been made to estimate each different type of constituent on a quantitative basis, and, although the percentages plotted are subject to some error due to personal judgment inherent in such ratings, it is believed that the significant trends are correctly portrayed.

Correlation of the I-T Diagram With End Quench Hardenability

The sequence of microstructures in the end quench hardenability bar is fundamentally related to the pattern of austenite transformation depicted by the I-T diagram; however, since the latter represents transformation as it occurs at constant temperature rather than on continuous cooling, the relationship is implied and not always directly apparent from cursory inspection of the I-T diagram. Regarding transformation on continuous cooling as equivalent to an infinite number of isothermal treatments each at a successively lower temperature, it is possible to derive a cooling transformation diagram (C-T diagram) which facilitates interpretation of the I-T diagram in terms of hardening and other heat treatments involving transformation on cooling. Not all the necessary information is available to develop a strictly accurate C-T diagram from the I-T diagram; nevertheless an approximate diagram can be derived which is of value in relating the I-T diagram to hardenability data and to other heat treatments which involve continuous cooling.

In Fig. 6 (shown on the next page and, with micrographs, on p. 636-B) an attempt has been made to correlate the I-T diagram for 8630 steel with the hardenability results, through the medium of a derived C-T diagram.* The cooling curves used in the derivation were taken from data compiled by Boegehold and Weinman, who measured cooling rates at several points just below the surface along an end quenched bar. The method of deriving the C-T diagram was that of Grange and Kiefer (● *Transactions*, Vol. 29, 1941, p. 85) with certain allowances for the effect upon transformation to bainite or martensite of the relatively large amount of pro-eutectoid ferrite which may form in this steel. The derived C-T diagram should not be regarded as highly accurate; yet, despite its limitations, it bridges the gap between isothermal

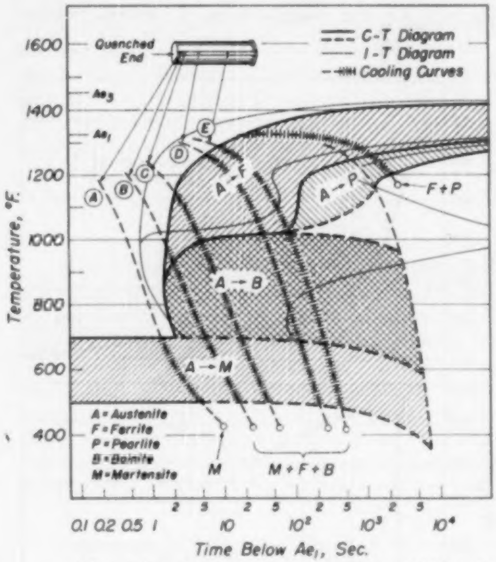
*Discrepancies between this diagram and that of C. A. Liedholm (*Metal Progress*, September 1944) for 8630 steel are probably due principally to differences in the manner of constructing the two diagrams. The time scale of Liedholm's diagram is *total time* to cool from the austenitizing temperature, whereas the time scale of our diagram is *time below* Ae_1 (or, for proeutectoid ferrite formation, time below Ae_3). In addition, there is a difference between the two 8630 steels, ours being probably the lower in hardenability.

and cooling transformation and helps to explain the origin of structures in the end quenched hardenability specimen. In interpreting the C-T diagram, each cooling curve should be followed downward from upper left to lower right; transformation occurs during the cooling interval spent in the cross-hatched areas, each kind of constituent (ferrite, pearlite, bainite, or martensite) being represented by a separate field on the diagram. Each of the cooling curves labeled *A, B, C, D* and *E* represents a point at a different distance from the quenched end of the hardenability bar as shown by the sketch at the top of the diagram.

Cooling curve *A* represents a point $\frac{1}{16}$ in. from the quenched end where the structure was entirely martensite; reference to the C-T diagram shows that this cooling curve intersects only the martensite field. Curve *B* is for a point ⅛ in. from the quenched end and represents slower cooling than *A*; it barely intersects the ferrite field, then cuts through the bainite and martensite fields. The structure at *B* should therefore consist of martensite, bainite and the merest trace of ferrite according to the C-T diagram, which is confirmed by the microstructure at this point. Curve *C*, ¼ in. from the quenched end, represents still slower cooling than *B*, and hence more ferrite and bainite are formed. At 1 in. from the quenched end, curve *D*, the structure is ferrite, bainite and only a small amount of martensite.

Finally, curve *E* represents cooling at a point 2½ in. from the quenched end where the cooling effect of the end quench is almost nil. Even with this slow rate, some martensite persists in the structure, which otherwise is composed of ferrite and a smaller proportion of bainite. In accordance with the way the cooling curves intersect the C-T diagram, ferrite increases in amount and occurs as larger and more nearly equi-axed areas as the cooling is slower. The prior rejection of ferrite enriches the remaining austenite in carbon and consequently modifies both the rate of bainite formation and its appearance, as compared with the isothermal bainite series. For this same reason martensite must form within an ever lower temperature range as the cooling is slower and more and more ferrite formed before the martensite region was reached on cooling. The precise effect of carbon enrichment of austenite by rejection of pro-eutectoid ferrite upon transformation to bainite and martensite cannot be quantitatively determined from available data, but the trend would logically be as indicated by the downward curvature of the upper and lower boundaries of the bainite and martensite fields and their extension toward longer times than indicated by direct derivation.

The curve representing slowest cooling bears no label and does not represent a point on the end quenched bar; this curve was measured for a separate specimen furnace-cooled at a rate much slower than any encountered in the end quench hardenability test. The structure in this specimen is ferrite and pearlite just as one would conclude from the way this curve intersects the C-T diagram; transformation was completed at about 1200° F., and consequently no bainite nor martensite is present. This curve and the corresponding photomicrograph (p. 636-B) are included, even



(Time below Ae_1, with respect to pro-eutectoid ferrite)

Fig. 6 — Correlation of C-T and I-T Diagrams With End Quench Hardenability Specimen of 8630 Steel

though they do not concern the hardenability test, in order to demonstrate the application of the C-T diagram to slow rates of cooling and also for comparison with micrograph *E* which contains bainite that might otherwise be mistaken for pearlite.

It has been demonstrated that the structures observed in the end quenched hardenability bar are in satisfactory agreement with predictions based on a C-T diagram derived from isothermal data. These structures are analogous to mixtures of isothermal products, although when an appreciable amount of pro-eutectoid ferrite separated, the bainitic portion of the structure did not closely resemble isothermal bainites formed in this steel in the corresponding temperature range.

Standardization of Toolsteels in Sweden*

THE recent standardization of toolsteel in Sweden is the result of close cooperation between steel works and consumers. It was considered a common interest of all parties concerned to bring about simplifications which would improve the quality of manufacture and at the same time reduce the cost of production and storage.

Difficulties of supply during and immediately after the recent war gave added urgency to the matter, but the greatest impetus to rapid action was perhaps the tendency of civil and military Government authorities and other large toolsteel consumers to adopt specifications of their own, often at variance with one another. This would have involved the risk that several grades of steel might have been adopted as standard for the same or similar purposes, with consequent difficulties in the steel works regarding storage and delivery.

Although the points of view of producers and consumers were sometimes at variance, the selection of standard grades of steel did not present insuperable difficulties. A compromise had to be reached between the reluctance of the consumers to experiment — at an extremely busy time — with unfamiliar grades of steel, and the necessity for the steel works to concentrate as far as possible on steels that could be sold on the export market. The guiding principles in the standardization work became, on the one hand, to select as far as possible the best steel for every requirement within the cost limits acceptable to the market, and, on the other hand, to adopt as standard those grades of Swedish steel which, according to the experience of the steel works, would be most suitable for the export market. It was hoped that the standardization would give to both producers and consumers the advantages of fewer grades, less capital investment in steel stockpiles with slow turnover, quicker deliveries, and greater uniformity in heat treatment by the consumers, and that it would also be an aid to military defense.

The eighteen standard steels are listed in the table below. Standardization of steels for quantity production of small tools was deferred for the time

(Continued on p. 678)

*Abstracted by Einar Öhman from an article by Ragnar Arpi (chief metallurgist, Uddeholm Steel Co., Hagfors, Sweden), *Verkstäderna*, Vol. 44, 1948, p. 166.

Approximate Compositions of Toolsteels Standardized in Sweden

Swedish Steel No.	ASM Handbook Type No.	Toolsteel	Brinell Hardness Max.	C	Si	Mn	Cr	Ni	Mo	W	Co	V
1780	IA	Carbon Toolsteel, 0.80% C	195	0.8								
1880	IA	Carbon Toolsteel, 1.0% C	195	1.0								
1885	IA	Carbon Toolsteel, 1.2% C	195	1.2								
2092	—	Low-Alloy "Nonshrinking"	240	0.95	1.5	—	1.0	—	—	—	—	—
2140	IIA1	Low-Alloy "Nonshrinking"	220	0.90	—	1.2	0.5	—	—	0.5	—	0.10
2260	IIB2	Alloy "Nonshrinking"	240	1.0	—	—	5.2	—	1.1	—	—	0.20
2310	IID2	High-Alloy "Nonshrinking"	260	1.5	—	—	12.0	—	0.8	—	—	0.20
2312	IIC1	High-Alloy "Nonshrinking"	280	2.0	—	—	13.0	—	—	1.2	—	—
2550	VIF2	Alloy Cold Work Steel	260	0.55	—	—	1.0	3.0	0.3	—	—	—
2700	—	Steel for Twist Drills, etc.	210	1.2	—	—	—	—	—	0.55	—	0.10
2705	—	Steel for Twist Drills, etc.	210	1.1	—	—	0.3	—	—	1.0	—	0.10
2710	IIIE	Chisel and Hot Work Steel	245	0.45	0.9	—	1.2	—	0.25	2.2	—	0.15
2730	IVF1	High-Alloy Hot Work Steel	250	0.30	—	—	3.0	1.7	—	9.0	—	0.30
2750	VC1	High Speed Steel	265	0.70	—	—	4.5	—	—	18.5	—	1.2
2752	—	High Speed Steel	290	0.80	—	—	4.5	—	1.2	18.5	2.5	1.6
2754	VD2	High Speed Steel	290	0.80	—	—	4.5	—	1.2	18.5	5.5	1.6
2756	VD3	High Speed Steel	310	0.80	—	—	4.5	—	1.0	18.5	10.0	1.6
2900	IC	Vanadium Alloy Chisel Steel	195	0.80	—	—	—	—	—	—	—	0.10

Movements Among Metallurgists

Thomas W. Lippert

Titanium Metals Corp., a joint subsidiary of National Lead Co. and Allegheny Ludlum Steel Corp., organized for the marketing of titanium metal, has appointed **Thomas W. Lippert** to be its general manager. Tom Lippert is widely known in the metals industry from his connection with *The Iron Age*, whose staff he joined in the early 30's as technical editor. He became editor-in-chief in 1946, succeeding John H. VanDeventer, and resigned this position in July of last year. During the brief interim, he has been manager of publications for American Institute of Mining and Metallurgical Engineers.

J. M. Hines, for the past eight years with C. I. Hayes, Inc., has accepted a position as sales engineer with the C. I. Thornberg Co., Huntington, W. Va.

William F. Aylard, formerly works manager of the Cleveland plant of Chase Brass & Copper Co., Inc., has been recently named chief engineer of the company.

Herman P. Rassbach, former works manager of the Midvale Co., has joined the Electro Metallurgical Division of Union Carbide and Carbon Corp. as metallurgical engineer with the development group. He will make his headquarters in Chicago.

Richard A. Fayram, formerly with the NEPA Division, Fairchild Engine and Airplane Corp., has been appointed lecturer in mechanical engineering at the University of California, Berkeley, Calif.

Babcock & Wilcox Tube Co. announces the appointment of **C. B. Marshall, Jr.,** to the sales force of the Chicago district sales office. Mr. Marshall has been in the general sales office of the company's welded tube div., Alliance, Ohio, since 1944.

Carl E. Swartz

Carl E. Swartz has resigned his position with Kellex Corp.'s applied physics laboratory in Silver Spring, Md., where he was division engineer in charge of research in high-temperature materials, to become chairman of metals research at Armour Research Foundation, Illinois Institute of Technology. An American authority on precision bearings for high speed machinery, Swartz was from 1935 to 1945 chief metallurgist for Cleveland Graphite Bronze Co.; in this position he devised many improvements in the handling of steel-backed copper-lead bearing alloys. He also continued to improve the technique of manufacturing bearings containing cadmium and tellurium, thus continuing work of the previous decade when he was metallurgist on the research staff of American Smelting & Refining Co.

Aurora Metal Co., Aurora, Ill., announces that **L. C. Newton**, St. Paul, Minn., is its sales engineering representative in the states of Minnesota and northern Wisconsin.

Roto-Finish Co., Kalamazoo, Mich., announces that **C. Heamon Castle** has been elected vice-president.

Paul Schwarzkopf

Paul Schwarzkopf, president of American Electro Metal Corp., Yonkers, N. Y., has been awarded the annual medal of Stevens Institute of Technology for outstanding achievement in powder metallurgy — a silver medal made by the process at the Institute. Dr. Schwarzkopf has been a leader in the powdered metal field in Europe and America for the last 40 years. Starting his career in Prague in 1911, he established his own company for the production of molybdenum and tungsten wires. After World War I, his firm's activities spread to Germany, Holland and Austria. In 1929 he set up American Electro Metal Corp. in this country and following his expatriation by the Nazis in 1936, he came here to live. Hundreds of patents and developments in the powder metal field are credited to him.

G. B. Grable is now employed as engineer at the U. S. Naval Aeronautics Development Center, Johnsville, Pa.

W. E. Bruse is now chief metallurgist of Shakeproof, Inc., division of Illinois Tool Works, Elgin, Ill.

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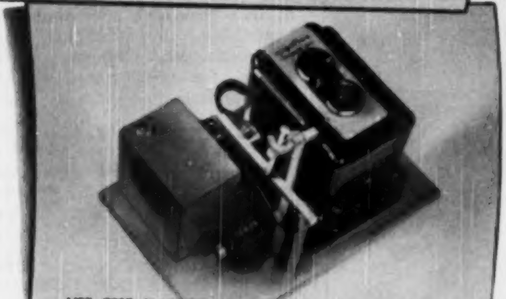

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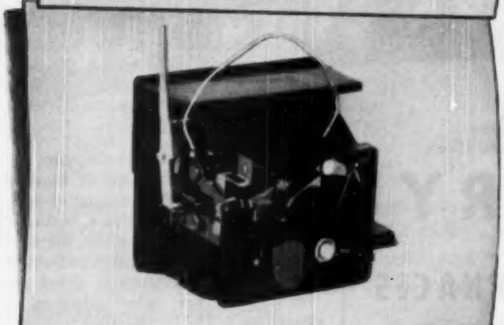

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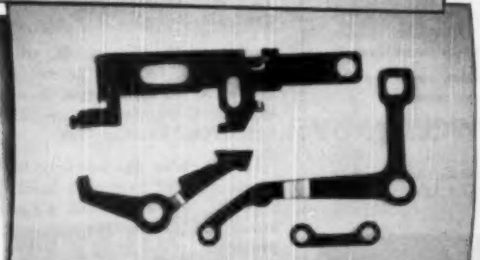

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WHY THE ARGOFLEX 75 GIVES CAMERA FANS

A Lifetime of Clicks without Kicks

Revere Brass used in shutter mechanism combines special tolerances and watch-like precision with durability and low cost

IN developing the shutter mechanism for their Argoflex 75 camera, engineers of Argus, Inc., Ann Arbor, Mich., had to cope with an unusually tough combination of problems. Production called for progressive die stamping operations, while to further complicate matters the stamped parts had to be constructed so as to incorporate the added feature of making double exposures impossible. The stock used had to be in strip form and without camber.

At the same time tolerances of 1/1000 to 2/1000 of an inch had to be maintained throughout the entire length of the strip, because the shutter parts had to function with watch-like precision. All of these requirements were necessary to maintain constant shutter speeds for consistent photographic results. In addition, the parts had to be durable, low in cost, and require only a minimum of hand finishing.

Together, Argus engineers and Revere's Technical Advisory Service worked on these complex problems. It was agreed that brass be used because of its workability and freedom from corrosion. Revere supplied a special stretcher straightened brass strip stock held to plus or minus .0007 thickness tolerance.

That this Revere brass strip more than adequately answers all the Argoflex 75 requirements for special tolerances, precision, durability and low cost, is borne out by its performance in operation. Said the Argus people: "Your (Revere's) Technical Advisory Service assisted us in solving these problems to our unlimited satisfaction."

In order to determine how the camera shutter mechanism would stand up in use, Argus has designed the machine you see at left which automatically winds and snaps the camera. These tests which are constantly being made on current production show the life of the camera to be far greater than the number of pictures the average photographic fan takes in an entire lifetime.

Perhaps Revere Brass or some other Revere Metal can be of help in developing or improving your product —cutting your production costs. Why not tell Revere about *your* metal problems? Call the Revere Sales Office nearest you today.

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230 Park Avenue, New York 17, New York

Mills: Baltimore, Md.; Chicago, Ill.; Detroit, Mich.; Los Angeles and Riverside, Calif.; New Bedford, Mass.; Rome, N. Y.— Sales Offices in Principal Cities, Distributors Everywhere.

Personals

Robert W. Hunt Co., Chicago, announces the appointment of **H. H. Morgan** as general manager. He will continue to be vice-president and chief engineer.

William L. Drake has been transferred by Crucible Steel Co. of America from supervisor of wire mill metallurgical laboratory, Sanderson-Halcomb Works, Syracuse, N. Y., to the Philadelphia sales branch where he will be a sales engineer.

Paul S. Methé, who received his Bachelor's degree in January 1950, has joined the Aluminum Co. of America's research laboratories at New Kensington, Pa., as a research metallurgist.

E. W. Harwell has been recently elected president of Hamilton Steel Co., Cleveland, subsidiary of Fort Duquesne Steel Co.

Hudson T. Morton has established the Morton Bearing Co., Ann Arbor, Mich., which has purchased the machinery and assets of New Britain Bearing Co., Inc.

Following graduation from Bradley University in February 1950, **Harold F. Neuberger** is now working for the Micro Switch Div. of the Minneapolis-Honeywell Regulator Co., Freeport, Ill., as a quality control technician.

Vernon E. Anderson is now employed at the Carnegie-Illinois Steel Corp.'s south works, Chicago, Ill., as junior observer.

Albert Raitzer, formerly metallurgist with the Sheldrick Mfg. Co., is now engaged as metallurgist on tool and die problems with the Tapco Div., Thompson Products, Inc., Cleveland.

Alvin Shames, after graduating from Colorado School of Mines, was appointed graduate assistant in the division of metallurgy at Pennsylvania State College.

H. Raymond McCoy, for the past 10 years chief metallurgist at the Ohio Steel Foundry Co., is now connected with Texas Electric Steel Casting Co., Houston, Tex., as chief metallurgist.

Clinton Webster, a recent graduate of the Michigan College of Mining and Technology, has accepted a position as junior metallurgist with the Cerro de Pasco Copper Corp., Oroya, Peru, South America.

R. Doughton, Jr., has been transferred to duty in the specifications and standards branch, Office of Naval Material, Navy Department, Washington, D. C.

Peter A. Frasse and Co., Inc., announces the appointment of **Bernard Dolan**, formerly manager of merchandising, to the position of manager of sales. He is assigned to the New York, New Jersey and Connecticut areas and will continue to direct advertising and sales promotion activities.

Roman Nowicki is now attending the University of Michigan Graduate School.

Robert M. Shapiro, who was formerly a research fellow at the University of Pittsburgh, is now an engineer-in-training at the Scientific Supply Co., Houston, Tex.

J. B. Caine, formerly director of research of Sawbrook Steel Castings Co., has established a technical consulting business on casting problems.

After completing work for his B.S. at the University of Wisconsin, **Edwin D. Baugh** has started to work for the Westinghouse Electric Corp., atomic power division.

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NO indeed, all pots are not alike. Take for example these ACCOLOY CYANIDE POTS. Every size and shape for each particular job and use. And they differ from all other competitive makes because of their thin wall construction.

Yes, 3/8" wall section in the smaller sizes and 1/2" wall in the larger ones. Made by a casting technique that *controls grain size* throughout the entire pot. No more enlarged grain size under heads or risers.

While a THIN-WALL pot is more difficult to cast, the resultant finer grain size obtained gives longer service life and takes less heating-up time — two vital factors in PRODUCTION ECONOMY.

Before shipping, each pot is thoroughly pressure tested — spot X-rayed — and solution tested to make certain it is free from porosity.

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ALLOY CASTING CO. (DIVISION)
CHAMPAIGN, ILLINOIS

HEAT RESISTANT CASTINGS
ACCOLOY
STAINLESS STEEL CASTINGS

ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS

Personals

Following graduation from Colorado School of Mines, **Daniel Oakland** ⊜ has been named a sales engineer trainee at the Whiting Corp., Harvey, Ill.

C. E. Makepeace ⊜ has recently been appointed process control metallurgist of Algoma Steel Corp., Ltd., Sault Ste. Marie, Ont., Canada. He was a May 1949 graduate of McGill University and attended Wharton School of Finance and Commerce.

Clinton P. Mott ⊜, formerly production manager of Christensen Diamond Products Co., has established a consulting service in Salt Lake City, Utah, specializing in industrial plant design and operation.

Frank W. Meblett ⊜, a recent graduate from the University of Cincinnati, is now a metallurgical engineer with the Sawbrook Steel Casting Co., Lockland, Ohio.

Albert H. Fleitman ⊜, formerly with the U. S. Reduction Co., is now metallurgist for Inland Steel Co., Indiana Harbor, Ind.

J. J. Zimmerman ⊜, formerly chief production engineer of Playboy Motor Car Corp., is now general supervisor of the planning section, receiver division of General Electric Co.'s Syracuse, N. Y., plant.

Horace A. Johnson ⊜ has accepted a position as metallurgical observer with the Carnegie-Illinois Steel Corp., Gary, Ind.

Formerly with the New York Air Brake Co., **Harry C. Burnett** ⊜ is now metallurgist at the National Bureau of Standards, Washington, D. C.

Following graduation from Missouri School of Mines, **Lowell T. Smith** ⊜ has been employed by Lewin-Mathes Co., St. Louis, Mo., as production supervisor.

Edward P. Gruca ⊜ has been transferred by Pullman Standard Car Mfg. Co. from the Pullman Car works in Chicago to the research and development division in Hammond, Ind., where he will direct the welding research activities.

Robert A. Woodside ⊜, formerly works metallurgist at the Donora, Pa., plant of the American Steel & Wire Co., is now works metallurgist with the Lewis Bolt & Nut Co. in Minneapolis, Minn.

Following graduation from Missouri School of Mines and Metallurgy, **John P. McGowan** ⊜ has accepted a position as metallurgical engineer with the Eagle-Picher Co., Hillsboro, Ill.

After graduating from the University of Wisconsin in January 1950, **Robert E. Hueschen** ⊜ has accepted employment with the General Electric Co. as a metallurgical engineer in the training program at Hanford Works, Richland, Wash.

D. M. Johnson ⊜ has been transferred by the Western Electric Co. from the Hawthorne Works at Chicago to be the metallic raw material engineer at the company's new plant in Indianapolis.

Donald G. Dewey ⊜, who graduated from the University of Notre Dame in January 1950, is now employed at the Northwestern Steel & Wire Co., Sterling, Ill., as assistant metallurgist.

Charles F. Ramseyer ⊜ and **J. R. Miller**, both formerly associated with H. A. Brassert & Co., have formed a consulting engineering partnership for general engineering practice under the name of Ramseyer & Miller, Inc., New York City.

Two Type HD-3684 Hevi Duty Vertical Retort Furnaces in operation at The American Metal Treating Company Cleveland, Ohio.

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"Extra large pieces are no problem with Hevi Duty Furnaces," says Mr. J. L. Teegarden of the American Metal Treating Company. "We can harden 7 ft. rolls or 3 ft. diameter gears without scale or decarburization."

THIS is a typical example of how one of Cleveland's long-established heat treaters found that Hevi Duty Furnaces provide for flexible operation which helps meet the demands of exacting customers. Consistent, uniform results are possible because Hevi Duty Vertical Retort Furnaces are designed for multiple zone temperature control and rapid circulation of the furnace atmosphere.

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Melting and Casting of Nonferrous Metals*

THIS SYMPOSIUM consisted of six papers. The first was rather general; the others dealt specifically with copper and various copper alloys.

The first paper, "Melting and Casting of Nonferrous Metals", by G. L. Bailey and W. A. Baker (25 pages, 4 plates, 29 references), was primarily a review of available information. The requirements of quality billets (ingots) are outlined with reference to the more common defects (folds, inclusions, exudations, cracks, internal cavities). This leads into a description of the solidification process. Next comes a discussion of dissolved gases and the removal of them; then, a description of open-slab casting, top pouring, and nonturbulent pouring, with two pages on the practical aspects of obtaining directional solidification. The most important development of directional solidification is in the continuous and semicontinuous casting methods used to a limited extent for copper alloys and more widely for aluminum alloys. As these methods of pouring involve rapid cooling after solidification, large residual stresses are developed in the casting. Nevertheless, these processes approach more nearly to the ideal requirements of a casting process than any of the older methods. The vertical fall of metal into the mold is short, so that the problem of mechanically entrapped gases and oxides does not arise. At the same time, sufficient heat is extracted from the metal in the desired axial direction to prevent "bridging", and the resulting casting is notable for its internal soundness.

The paper is concluded with a discussion of macrostructure and microstructure.

The second paper, "Production of Refined Copper Shapes", by R. H. Waddington (14 pages, 4 plates, 6 references), gives a thoroughly up-to-date account of the procedures employed by International Nickel Co., at Copper Cliff, Ont. Blister copper from converters is

(Continued on p. 652)

*Abstract of "Symposium on Metallurgical Aspects of Nonferrous Metal Melting and Casting of Ingots for Working"; first published in the *Journal* of the Institute of Metals, January 1949; republished, with discussion, as No. 6 in the Institute of Metals Monograph and Report Series. London. ($2.50.)

Melting and Casting of Refined Copper

(Starts on p. 650)

transferred while molten to the 300-ton reverberatory furnaces a mile and a half away, where it is suitably treated and then cast into 580-lb. anodes for the electrolytic department. Electrodes are of high-purity graphite, 18 in. in diameter, to carry 4000 kva. Consumption of electrodes is about 4 lb. per short ton of copper melted. Each furnace is connected to a well-insulated and protected launder system, leading to the pour hearths which hold about 5 tons of metal and allow variation of flow rate and temperature control as metal is poured into the molds. Melting is continuous. Air is admitted to the furnace to keep the oxygen content of the metal at about 0.01%. This minimizes the influence of the hydrogen present. A typical analysis of the furnace atmosphere is 16.8% CO_2, 3.1% CO, 0.6% O, 0.5% H, H_2O not determined, the remainder or about 75% N. It is assumed that unsoundness results chiefly from the following reactions:

$$Cu_2S + 2\,Cu_2O \rightarrow 6\,Cu + SO_2$$

$$H_2 + Cu_2O \rightarrow 2\,Cu + H_2O$$

Although the solubility of carbon in molten "oxygen-free" copper just above its melting point is about 0.0001%, it must be remembered that this amounts to about 10% of the volume of the copper, and that oxidation of this much carbon may cause porosity. The Copper Cliff process presumes that the solubility of carbon in copper containing 0.01% oxygen is probably too low to be of practical significance.

The whole matter of mold dressing is given in great detail. The molds are manufactured in the company's own shops from electrolytic tough-pitch copper to which silver has been added to maintain surface quality during the life of the mold. They are drilled to provide a system of connected internal channels for the circulation of cooling water. The assembly of casting-wheel molds is connected to a suitable heat exchanger and about 500,000 B.t.u. per ton is removed.

In pouring, the objective is to obtain a rate of solidification that is not so rapid as to cause shrinkage cracks or voids, and yet fast enough to give essentially unidirectional cooling and to deter reaction-unsoundness. Mold temperatures are prevented from rising more

(Continued on p. 654)

Melting and Casting of Aluminum Bronze

(Starts on p. 650)

than 30° F. by means of the water circulation. Records and inspection are most carefully devised; most of the Copper Cliff specifications are more exacting than those of the B.S.I. or A.S.T.M. The phosphorus-deoxidized copper has a residual phosphorus content between 0.007 and 0.060%.

This paper illustrates the importance of small details. For instance, the statement that bone ash was used for a mold dressing might seem like a sufficient specification. But the practitioner in the casting shop will be glad to know that one type of bone ash that was found to be quite unsatisfactory for molds used in casting horizontal shapes was acceptable for vertical castings. Every detail has to be taken into account.

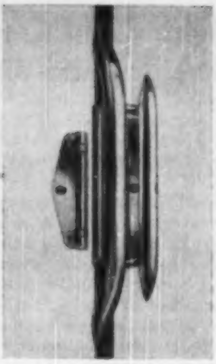
In A. J. Murphy and G. T. Callis' paper, "Melting and Casting Aluminum Bronze Ingots for Subsequent Working" (14 pages, 2 plates, 3 references), it is pointed out that aluminum bronzes, because of their high solubility for hydrogen, can be particularly plagued with pinhole porosity in the ingot if any considerable amount of hydrogen is absorbed during the melting of the metal. The authors point out that if the aluminum oxide film is allowed to form on the molten metal and is not removed or disturbed, there is no pinholing in the finished casting unless the metal is grossly overheated or is retained molten for a very long time. The simplest explanation of this observation is that the film is impermeable enough to prevent hydrogen and other gases from gaining access to the molten metal except at a very slow rate. If the oxide film is diluted by the use of fluxes, the protective action no longer exists, as Bailey and Baker also observed. The gases pass into the metal with resulting pinhole porosities in the ingot unless rapid chilling is employed. The authors point out that fluxes are thus not to be used indiscriminately, and are really justified only in the remelting of drossy skimmings and residues, in order to reduce losses due to entrapment of valuable metal in the nonmetallics.

On the other hand the aluminum oxide which is so beneficial for maintaining a gas-free melt will give rise to very poor surface in the casting if top-poured permanent molds are used. For this reason the Durville process is of special advantage in casting these alloys. In this well-known process the surface of the metal is maintained unbroken during casting and a billet of exceptionally high surface quality can be obtained.

As Murphy and Callis point out, the freezing range of the aluminum bronzes is quite narrow (15 to 25° F.) so that the alloy may form a deep central pipe, especially in long narrow castings. For this reason the Durville process is limited to ingots whose ratio of length to diameter is of the order of 8 to 1. For castings longer than this, the general practice is to fall back on the ordinary method of top pouring, which necessitates scalping the ingot, although many alternate methods involving bottom pouring and other means have been proposed.

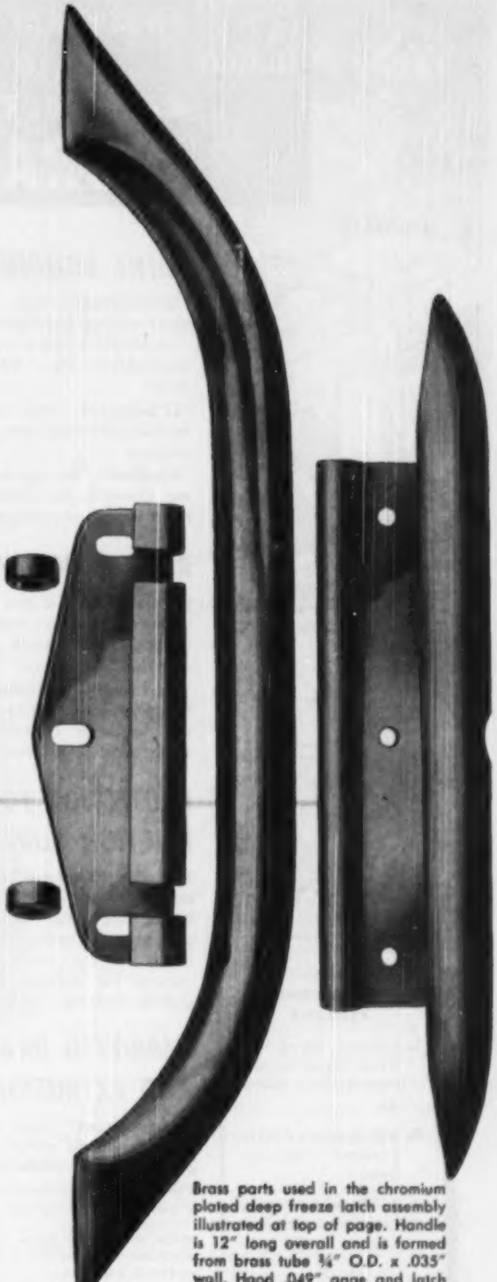
Murphy and Callis describe the defects which may be found in Durville-cast ingots, including ripple marks on the surface caused by unsteady operation of the machine, patches of oxide or dross on the surface resulting from insufficient

(Continued on p. 656)



SHORT, SHORT STORY:

1. Latch assembly on deep freeze cabinet was made of steel.
2. Parts rusted—plating peeled—owners complained.
3. "Covert" switched to brass—saved customer 30¢ a set.
4. Better product—no complaints—everybody happy.



Brass parts used in the chromium plated deep freeze latch assembly illustrated at top of page. Handle is 12" long overall and is formed from brass tube ¾" O.D. x .035" wall. Hood .049" gage and latch .087" gage are formed from brass strip. Rollers are turned from ½" diameter brass rod. 5087

IT'S AS SIMPLE AS THAT. Cost of the brass (weighing less than a pound in the finished parts) was higher. Fabricating cost and procedure were exactly the same. However, the cost of buffing the 70-odd square inches of exposed area, before plating, was cut in half and this, plus the elimination of rejected parts, effected a net saving of 30¢ per set over the extra cost of the metal.

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R.S. *Chromium plating on brass is brighter . . . less costly . . . longer-lasting*

Melting and Casting of Aluminum Bronze

(Starts on p. 650)

skimming of the metal in the reservoir, a central shrinkage pipe caused by pouring at too high a temperature or by attempting to cast ingots with too great a ratio of length to diameter, and a fine longitudinal intercrystalline crack on the ingot surface usually found after pouring from too high a temperature, particularly with a new mold.

This paper contains an excellent photograph showing the superiority of Durville-cast ingots compared with top-poured ingots.

In the discussion F. C. Evans said that while the authors had used a mechanically operated Durville casting assembly, he had obtained equal if not superior results in some respects from a Durville machine operated manually. He emphasized that the "speed of tip" was very important, especially when you are approaching the horizontal and are just crossing it and require a faster speed. Furthermore, the manually operated machine is cheap to manufacture and has no complicated mechanical or electrical mechanisms to maintain. Ingots weighing 400 lb. are successfully cast.

In the paper "Application of Flux Degassing to Commercially Cast Phosphor Bronze" (14 pages, 1 color plate, no references), N. I. Bond-Williams discusses bronzes containing from 2 to 10% tin with phosphorus 0.15 to 0.2%. He describes two general casting procedures — the old and the new.

In the older method 160-lb. salamander crucibles heated in a coke-fired natural-draft furnace were charged with copper and phosphor bronze scrap and a liberal addition of charcoal. The charge required 1¼ to 1½ hr. to melt down. At the end of the melt phosphor copper was stirred in and then tin. The melt was poured without a strainer on a sloping mold which had been dressed with a heavy coat of seal oil, French chalk and powdered charcoal, and warmed. Slab molds were 1 to 1¼ in. thick and 3 to 12 in. wide. Wire bar molds were 1⅝ in. square by 5 ft. long. The results of such a technique gave rise — and little wonder — to the following problems:

The slabs showed a concavity on the rolling surface due to lateral contraction resulting from the high

(Continued on p. 658)

Flux Degassing of Phosphor Bronze

(Starts on p. 650)

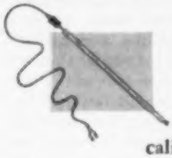
pouring rate and lack of directional solidification. This concavity could lead to cracked bars and subsequent rolling. The ingots showed pronounced tin sweat due to the lateral contraction, as well as the high gas content, which must have resulted from the melting procedure. Mr. Bond-Williams states that $\frac{1}{8}$-in. scalp from each rolling surface (approximately 20% scrap!) was a regular process to eliminate the tin sweat. The reducing conditions employed during melting resulted in unsound ingots. In addition the practice of casting on sloping molds gave low mold life.

The whole technique was gradually revamped. The furnace was improved by adopting the "Wigley" design of grate for the pit furnaces and this decreased the melting time by about 50%. The charges were melted down over an oxidizing flux of equal weights of dry sand, mill scale (CuO) and fused borax, equal to 3% of the weight of the charge. Just before pouring, the flux was thickened with dry sand and skimmed off. The tin was added and finally the melt was deoxidized by adding 15% phosphor copper. The melt was poured at a high temperature into a steel tundish with fireclay lining and graphite insert and then into vertical book-type cast-iron molds having a massive bottom for directional solidification and fitted with a multiple-hole strainer with graphite inserts. The molds were dressed with a thin coat of volatile oil and then wiped with a rag. The combination of a high pouring temperature and a slow pouring rate together with a chilled-bottom mold produced directional solidification which reduced the concavity of the bar. The use of an oxidizing procedure during melting produced internal soundness. The combination of directional solidification and an oxidizing melting procedure eliminated tin sweat to the extent that scalping was omitted. It need hardly be noted that such a marked improvement within a ten-year period was due partially to the improper technique used in the former process.

Maurice Cook and N. F. Fletcher's subject was "Melting and Casting of Brass" (20 pages, 11 references). Taking the word brass to cover binary alloys of copper with 20 to

(Continued on p. 660)

For accurate temperature measurement, use meters calibrated for Chromel-Alumel thermocouples



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And for good reasons, too. Because CHROMEL-ALUMEL thermocouple wire carries a positive accuracy guarantee . . . ±5° F. at temperatures up to 660° F., and ±¾% from 660° F. and over. It's highly responsive to temperature fluctuations . . . so resistant to oxidation that you need not pack the protection tube . . . and it maintains its fine accuracy over longer periods of time than any other base metal thermocouple material. So if you're responsible for accurate temperature measurement, better check your pyrometers to make sure they're properly calibrated, then specify couples by name . . . CHROMEL-ALUMEL thermocouples. Available through your instrument manufacturer or pyrometer service company.

PS-And while you're at it . . . complete your chain of accuracy with CHROMEL-ALUMEL "extension" leads. For, by using wires of identical compositions for both couples and leads, you eliminate all possibility of "cold-end" errors.

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**the [illegible] ickel-chromium resistance alloy that first made electrical heating practical*

Melting and Casting of High-Zinc Brass

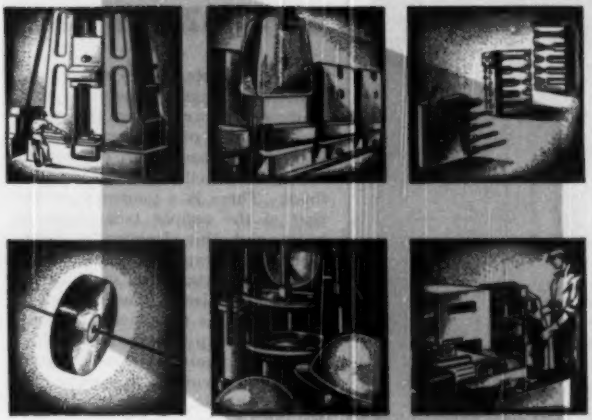
(Starts on p. 650)

43% zinc, as well as more complex alloys containing one or more additional elements in much smaller proportions, they considered brass-melting practices from the metallurgical standpoint. In general the brasses are easier to produce than aluminum bronzes, tin bronzes or silicon bronzes.

Melting units are described briefly. A reminder is given that the brass alloys are not sensitive to gas pickup, nor do they suffer much more than loss of zinc by oxidation. This gives greater latitude as to the type of furnace used. For repeat melting of the same alloy low-frequency induction is by far the most favored method. Loss of zinc by volatilization is, of course, an ever-present factor. The authors recommend a covering of charcoal which prevents the inward diffusion of oxygen and the outward diffusion of zinc. The two reacting elements meet in the charcoal layer, forming zinc oxide which blocks the interstices in the mechanical barrier and so increases its effectiveness. The disturbance of the cover results in the immediate evolution of zinc vapor and the formation of a cloud of zinc oxide fume. Some years ago one of the authors made an extended study of metal losses during brass melting and, in reporting on the losses resulting from varied operational conditions and protective and fluxing treatments, showed that the loss in low-frequency induction furnaces could be kept below 1% by covering the residual metal with a layer of charcoal before the start of charging, and, when all the metal was melted, adding a mixture of borax and common salt which was stirred into the layer of charcoal and dross, all of which was skimmed off before pouring. Phosphorus is not commonly added to brass. The addition of about 0.05% metallic arsenic is referred to as preventing dezincification under service conditions.

Whereas cast-iron molds used to be the rule, the advantages of water-cooled copper molds have been definitely established. Nevertheless, some very satisfactory castings are still made in iron molds. The main trouble with iron molds is the cracking of the mold surface. Copper-cooled molds are constructed with relatively thin face

(Continued on p. 662)



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Melting and Casting of High-Zinc Brass

(Starts on p. 650)

plates of wrought copper; the main framework, including the water jacketing and piping arrangements, is of steel or cast iron. The copper facing is normally only about ½ in. thick. There is a tendency on the part of the copper face plates to bulge and this frequently determines the scrapping of the plates.

The importance of mold dressing is emphasized. The function of the dressing is to protect the mold surface and prevent the molten brass from coming into contact with it, and to provide an insulating film which controls the heat flow from the solidifying metal to the mold. Dressings fall into two types—flaming and nonflaming. Flaming dressings are generally used, as they fill the mold with a reducing atmosphere almost as soon as pouring starts and help to protect the stream of molten metal from oxidation. They also have an appreciable effect in refining the crystal structure of the casting. The materials used for flame dressing may be oil of various kinds, petroleum jelly, tallow or resin, or a mixture of these, with a filler of powdered charcoal, talc, or china clay. Nonflaming dressings use bone ash or lampblack applied dry or as an aqueous suspension with or without a wetting agent to improve the uniformity of spreading. Resin dressings are to be preferred for iron molds but oil-base ones with powdered charcoal for water-cooled molds. Ninety-five per cent of the charcoal should pass through a 240-mesh sieve; coarse particles give trouble. All mold surfaces should be kept clean.

The desired conditions of pouring are a short stream, smooth and unbroken, and avoidance of the carrying over of dross and other foreign matter into the mold. Vertically poured molds have in general superseded inclined pouring. Reasons are given for this. Attention is drawn to the fact that for brasses containing aluminum the mechanical aspects of pouring are of special importance. A dressing of any nonflaming type should be used to avoid turbulence.

Reference is made to the Durville process. Large vertical castings of aluminum brass can be consistently and satisfactorily made by direct pouring into copper-face

(Continued on p. 670)

ENGINEERING DIGEST OF NEW PRODUCTS

30-INCH TABLE MODEL ELECTRON MICROSCOPE: A greatly simplified table-model electron microscope, only 30 in. high, has been developed by the Radio Corp. of America to sell for less than $6000.

Of revolutionary design, employing for the first time permanent magnet lenses requiring no stabilization circuits and controls, the new RCA Permanent Magnet Electron Microscope will provide useful magnifications up to 50,000 diameters by photographic enlargement, with direct magnification in the instrument ranging up to 6000 diameters. It has the same 50,000-volt accelerating potential as the Universal Model, RCA spokesmen disclosed, and is more than 20 times as powerful as the best optical microscope, with a depth of focus 150 times as great.

The availability of a satisfactory and relatively inexpensive electron microscope is certain to further the use of electron microscopy as a routine tool for metallographic examination, the company stated.

A unique advantage in time-saving and convenience is afforded by an engineering advance which for the first time permits insertion of specimens into the evacuated column, and their removal, without breaking the vacuum. In addition photographic plates may be changed without admitting more than a small amount of air to the column. As a result, pumping time between plates is reduced to only 90 sec.

To change specimens the operator needs only to pull out of the column a sliding rod containing the specimen holder, make the change, and push the rod back in place. A new type of specimen holder facilitates pre-preparation of specimens so that production-line procedures may be followed in running one specimen after another without any delay.

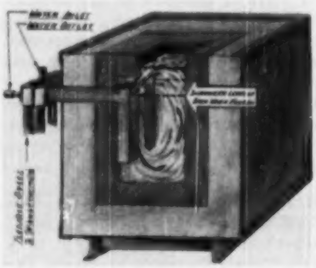
For further information circle No. 342 on literature request card on p. 668A

SUBMERGED ELECTRODE FURNACE: The Ajax Electric Co. is offering the Ajax Hultgren Salt Bath Furnace equipped with the newly patented submerged electrodes. The improved design is recommended for use with salt baths operating at temperatures from 1700 to 2400° F. as well as for exceptionally deep baths.

Basically, the submerged electrode design is similar to that of the standard Ajax furnace. However, instead of the electrodes entering from the top of the bath, they enter through the back-wall of the furnace just below the surface of the bath. They are closely spaced to produce electrodynamic stirring action common to all Ajax Salt Bath Furnaces thus assuring rapid heating and temperature uniformity within 5° F. The submerged electrodes are so positioned that, should the bath freeze from any cause (such as power interruption, malfunctioning of control equipment, etc.), the salt will shrink sufficiently to expose the electrodes for restarting in a manner similar to the standard Ajax furnace.

Specifically, submerged electrodes are recommended for deep baths for heat treating long work from 1100° F. upward; for the high heat unit used in hardening high speed steel tools at 2200 to 2375° F.; for high-carbon high-chromium dies at 1850° F.; and for all operations carried out in neutral salts above 1700° F. such as neutral hardening carbon and alloy steel, annealing and hardening stainless steel, heating for forging and brazing.

The primary advantage of using submerged electrodes for high-temperature work is that the life of the electrodes is greatly extended because, being totally submerged, they are not exposed to the severe oxidizing action which takes place at and above the bath surface. Users are now experiencing an electrode



life of from six months to three years (depending upon the number of operating hours per day, the operation and the operating temperature). Electrode replacement is not as easy as with the standard design although it is less frequent. Since the use of submerged electrodes is at present restricted to use with ceramic pots, the design is not recommended for cyanide hardening, carburizing, descaling, cleaning, desanding or for use with nitrate salts since the much cheaper and long-lived welded steel pots give best service for these applications.

In the submerged electrode furnace the exposed bath surface is reduced to a minimum, namely, the desired working area only. This reduces power consumption as much as 30% on high-temperature units. The restricted bath surface also reduces sludge formation. The bottom of the pot is free from live electrical parts or circuits since the electrodes are closely-spaced and set against the back-wall. The top of the furnace is free from obstructions and the entire assembly is enclosed in a steel casing.

All of these design features result in a furnace that is easily charged and discharged, easy to keep clean, readily desludged, and one in which the heating current is effectively prevented from entering the work and overheating it.

For further information circle No. 343 on literature request card on p. 668A

METAL CLEANER: A new prepaint metal-cleaning material, Compound No. 33, is announced by Oakite Products, Inc. This material removes all rust and prepares metal for paint in a single procedure.

Service report describes Oakite

(Continued on p. 664)

ENGINEERING DIGEST OF NEW PRODUCTS

(Continued from p. 663)
Compound No. 33 as having solvent and detergent properties which are extremely effective in removing stamping and forming oils, rust preventives, carbon smuts, soldering and welding fluxes, identification inks and similar soils. In addition, this material is said to contain acid ingredients that act on rust, heat scale, tarnish and other oxides; to have special accelerating agents that make rust removal (along with removal of oil) an amazingly fast operation. Thirdly, the service report states, this material has the ability to convert the surface layer of metal into a thin film of insoluble phosphates, which provides an excellent bond for paint. Material is said to have similar etching and conditioning action on aluminum sheets and aluminum castings.

For further information circle No. 344 on literature request card on p. 668A

HEAT AND CORROSION RESISTANT COPPER WIRES: Heat resistant nickel-clad copper wires which provide the good electrical conductivity of copper combined with the heat and corrosion resistant properties of nickel have been announced by the Parts Div., Sylvania Electric Products, Inc.

Sylvania is specializing in diameters ranging from 0.010 in. to 0.005 in. which are particularly well-suited for stranding and for lead wire applications where high-temperature working of hard glass frequently renders solid copper wires brittle and unworkable, as in the processing of high wattage incandescent lamps and electron tubes.

Stranded conductors of nickel-clad copper conductors are also finding increasing applications in electrical leads for aircraft, electric furnaces, electric ranges and other home appliances, jet engines, and a wide range of laboratory and industrial equipment where high temperature or corrosive atmospheres tend to make solid copper conductors brittle and unreliable.

Production of nickel-clad copper wire for these applications is controlled so that a practically uniform ratio of nickel to copper is maintained through a series of cold drawing operations in which the nickel-cladding ranges from 27 to 29%. During the process perfect bonding of nickel to copper is obtained. Good workability and electrical characteristics are assured through heat treating or annealing at frequent intervals and after final drawing.

Automatic production equipments also assure uniform, close tolerance, high-quality wire in any quantity. Final drawing of fine wire is fast, ranging from 2500 to 3000 ft. per min. or up to 34 miles per hour. This material is being marketed under the brand name "Kulgrid".

For further information circle No. 345 on literature request card on p. 668A

TIN CONTENT INDICATOR: A new portable direct-reading indicator for the determination of the ratio of lead and tin content in solder has just been released by Wheelco Instruments Co.

With the Wheelco Portable Tin Content Indicator, up to 7% tin content of lead alloys may be tested in a matter of seconds.

Application of this new instrument by users of solder, such as manufacturers of tin cans, etc., eliminates time-consuming laboratory tests and results in considerable savings and improved product quality.

For further information circle No. 346 on literature request card on p. 668A

A MODERN FLASH ANNEALING FURNACE: The continuous "flash" annealing of aluminum sheets in a new furnace developed by Storky Engineering, Ltd., heats the aluminum to its annealing temperatures in 2 or 3 min. to give recrystallization of the structure of the material and elimination of rolling line without allowing time for subsequent grain growth.

The plant which has been installed is continuous, handling single sheets up to 5 ft. 6 in. wide and circles down to 5 in. diameter at the rate of 1 ton per hour and consists of a loading conveyer interlaced with the furnace conveyer which is interlaced with the cooling conveyer which finally is interlaced with the unloading conveyer. Each conveyer consists of a series of ropes tensioned and supported to present a system very well adapted to conveying and transferring the work. This transfer of the work from one section of the conveyer to another is exceptionally smooth and special attention has been given to all conveyers to avoid marking of the polished finished work; in particular the loading and unloading conveyers have nonmetallic ropes and the furnace and cooling conveyers have specially constructed ropes and fasteners with individual tensioning to each rope.

Air circulation is adopted, two large-volume centrifugal-type high-temperature fans placed towards each end of the furnace supply air through the heater batteries into two sets of distribution ducts from which the air is directed onto the work. Further means are adopted to multiply the number of times the air is deflected over the work before it is returned to the fans and heaters. This method of two independent balanced air-circulating systems gives a true aerodynamic balance to the furnace and the total weight of air circulated is substantially greater than what would be considered even modern practice, with the result that the most rapid heat exchange takes place at the available temperature lead.

There are two heater batteries, one to each circulating system, and each battery is subdivided into lower ratings but the total loadings of the batteries are unequal. The cold "load" of the entering sheets is compensated by heavier rating of the heater battery at the ingoing end.

The annealing procedure is laid down for each thickness of sheet and circle as a function of furnace temperature and time and the infinitely variable speed gear provided on the conveyer drive has been calibrated to read annealing times. The furnace temperature is, of course, considerably above the temperature attained by the sheet and as each is exposed to the turbulent air circulation of the furnace, annealing time is reduced to a few minutes to achieve the close grain structure and greater ductility so much sought after by fabricators in aluminum.

For further information circle No. 347 on literature request card on p. 668A

ENGINEERING DIGEST OF NEW PRODUCTS

NEW 10 KILOWATT INDUCTION HEATER: A number of new features have been incorporated in the Type LI-10 Induction Heating Unit, recently announced by the High Frequency Heating Div., Lindberg Engineering Co.

On a 100% duty cycle basis, this unit is capable of providing more than 10 kw. into a suitable load.

Single and two-station models are available with high and low-impedance terminals at each station. Input power is 230 or 460 volts, 3 phase, 60 cycles.

Tubes are operated under optimum conditions for maximum life. All filament voltages are automatically regulated by constant-voltage-type transformers. The oscillator tube is air cooled, and a make-up-type, temperature-controlled water system cools tank components and work coils. This system features a water storage tank, built-in centrifugal pump, and temperature-operated valve. Advantages of this system are: greatly reduced water consumption, elimination of harmful condensation, less sensitivity to water pressure and unimpaired operation in hard water areas.

For further information circle No. 348 on literature request card on p. 668A

HIGH-VACUUM GAGE: The National Research Corp. has developed a new instrument for measuring high vacuum designed to fill the needs of the laboratory or plant high-vacuum installation. The pressure range covered is 1 mm. Hg absolute to 1×10^{-8} mm. Hg absolute. It controls two thermocouple-type vacuum gages and one ionization-type vacuum gage.

Thermocouple-type vacuum gages indicate pressures directly on the control meter from 1 mm. Hg absolute to 10^{-3} mm. by responding to the temperature of a thermocouple junction which is supplied with constant heat. Over the stated range, the temperature will be an exponential function of the pressure due to the varying heat conductivity of the rarefied atmosphere. By means of two thermocouple gages, measurements in this pressure range may be made at two points in the vacuum system.

One ionization-type vacuum gage is used to cover the range from 5×10^{-3} to 1×10^{-8} mm. Hg absolute on five ranges. Gas ions formed by collisions with a controlled electron beam are collected in the gage and resulting ionization current is measused on the calibrated amplifier. Pressure, which is proportional to the number of ions formed, is indicated directly on the meter of the control.

The wide range of pressures—1 mm. to 1×10^{-8} mm. Hg absolute—covers the whole useful working range of high vacuum. The control is suitable for production operation or for exacting laboratory work. The ionization gage has five ranges with full-scale readings at 5×10^{-3} mm., 1×10^{-4} mm., 1×10^{-5} mm., and 1×10^{-6} mm. with normal sensitivity. Normal sensitivity may be doubled for pressures below 5×10^{-7} mm.

A specially designed low-leakage shielded connecting cable is supplied. This eliminates errors at pressures below 10^{-6} mm. where the ionization currents are less than 10^{-7} amp.

A protective relay with very short time delay automatically turns off the ionization gage filament when the pressure in the system exceeds 1½ times the full-scale pressure for which the control is set. This saves expensive gage replacements. In preliminary tests, gages have survived more than 100 instantaneous pressure bursts from 10^{-3} mm. to atmospheric pressure.

A receptacle at the back of the chassis is connected so that auxiliary equipment such as alarm bells or relays in pump heater circuits can be controlled by the overload relay in the protective circuit for the ionization gage.

The filament emission is regulated at 1, 5, or 10 milliamperes at the operator's choice. The indication of small pressure changes without readjustment of emission is particularly useful for leak detection. This feature removes all the inconvenience in the form of emission adjustment necessary with the older ionization gage controls.

This control, by itself, will take care of all the normal gaging requirements of a high-vacuum system. Because the control handles two thermocouple gages — one for the high-vacuum side of the pump and one for the low-vacuum side—and because of the wide range of coverage, this control is extremely useful. It is unnecessary to use additional controls to make instantaneous comparative measurements in various parts of the vacuum system.

For further information circle No. 349 on literature request card on p. 668A

PRIMER FOR MAGNESIUM AND ALUMINUM: An outstanding primer for metals has recently been added to the line of Unichrome Product Finishes. Unichrome Primer AP-10, as it is designated, provides excellent adhesion on hard-to-coat magnesium and aluminum without chemical or electrochemical pretreatment. Other metals on which it is said to do an outstanding priming job are stainless steel, monel, tin, steel, brass, copper, and galvanized metals.

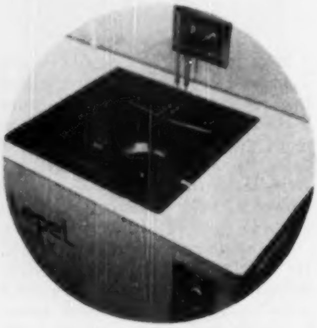
After the metal has been cleaned, the primer is applied by spraying or dipping. It can be air-dried or baked. An air-dried film of AP-10 becomes dust-free in 5 min. To obtain a coating with the greatest durability, baking schedules between 5 min. at 350° F. and 20 min. at 300° F. are employed. Both air-dried and baked coatings have exceptional adhesion and resistance to moisture. A baked coating has outstanding resistance to solvents, alcohols, naphthas, ketones, coal tar derivatives, and solutions of many metallic salts. Unichrome Primer AP-10 may be top-coated with lacquers, synthetics, or baking enamels.

For further information circle No. 350 on literature request card on p. 668A

ENGINEERING DIGEST OF NEW PRODUCTS

COMBINATION WORKTABLE AND QUENCH TANK: A new combination worktable and quench tank that can be easily attached to their vacuum tube or spark gap converters has been designed by Lepel High Frequency Laboratories, Inc.

With the sink cover on, this combination unit forms a handy worktable 29 x 56 in. for mounting work coils and fixtures. The center portion of the table top may be removed, uncovering a brass (or stainless steel) quench tank 24 x 24 x 18 in. deep, fed by a 1-in. water line, solenoid controlled. This sink can be used for water, oil or brine quenching. It will also accommodate the Lepel Roto Heating and Quenching Unit, designed for the hardening of gears, blanks, etc. Heating and quenching cycles are controlled by a three-circuit timer operated by pushbutton or footswitch.



This combination work and quench table is made from structural steel and is provided with a heat-resistant table top. It is also available as a worktable only, without the quench tank, timer and solenoid valve features.

For further information circle No. 351 on literature request card on p. 668A

BLACK FINISH FOR STEEL: Heatbath Corp. has developed a new method for black finishing of iron and steels.

The new Controlled Oxidation Pentrate offers a bath whose blackening power is positively controlled to operate at continuous peak efficiency, in single or double baths.

A two-component product — Pentrate S. S. — consists of a granular material which makes up the bulk of the bath and a second package — Pentrate Brix — containing compressed briquettes for controlling the oxidation rate and maintaining bath strength.

For single bath operation, 1 to 1½% of the bath weight per day is all that is required. For double bath operation, each bath will require ½ to 1% of their total weight in addition of Brix. The Brix contain 100% active materials. Brix also contain, in addition to active oxidizers, inhibitors which tend to reduce red and green stains on work and agents which blacken the steel deeper, denser and faster.

The New Controlled Oxidation Pentrate makes it possible for an operator to add either oxidizer or alkali when it is required. Alkali salts should be added to maintain the solution level and boiling point only. The Pentrate S. S. serves this purpose. It contains the right amount of oxidizer and alkali but does not contain an excess of either one.

Because of the wide operating range that this bath has along with the proper proportioning of the ingredients in the Pentrate S. S. bath, the resulting solutions are more fluid than the products in use today. A more fluid bath results in lower dragout costs. Neither of the two salts contains harmful poisons such as cyanides or lead compounds, etc., and no hazardous combustible chlorates are used.

For further information circle No. 352 on literature request card on p. 668A

DWARF BRINELL PRESS: New Type M 60/750 DWARF BRINELL PRESS Portable Hardness Tester is more versatile in its applications to all metals than any similar instrument, according to The R. Y. Ferner Co., Inc. With this low priced instrument, scientifically exact Brinell readings can be easily obtained for any metal from soft lead to hardened steel.

Definite pressures of 15.62 kg. to 750 kg. are indicated correctly, insuring a fine element of precision in its wide range. By fitting out the device with three sizes of ball penetrators separately mounted and interchangeable, tests can be made with 2.5 mm., 5 mm., or 10 mm. ball. The third feature is the design of three styles of holders or shanks readily adapting it for use in an ordinary vise or C-clamp; arbor press or sensitive drill or any other machine tool. Tests can be made with this instrument on rolls or molds, etc., directly during the machining operations if one wishes to investigate the nature of successive depths after each pass of the mills, turning tools or grinders.

For further information circle No. 353 on literature request card on p. 668A

DYNAMOMETERS: Newly developed 30,000, 40,000 and 50,000-pound capacity traction-type Dynamometers are announced by W. C. Dillon & Company, Inc.

Dillon Dynamometers are used for checking draw-bar pull, weight of bulky objects, tension in ropes or cables, static loads, etc. Large items that must be tested cannot fit into an ordinary laboratory tester and can only be handled by means of a Dynamometer. These new additions make this possible at a low cost and with a high degree of accuracy.

The dial diameter of these new units is 10 in. This makes for easy reading and fine increment breakdown. The instruments can be used indoors or outdoors wherever the job may be.

For further information circle No. 354 on literature request card on p. 668A

FOOL-PROOF DETECTOR PREVENTS EXPLOSIONS: A fool-proof flame detector which eliminates previous limitations in electronic safeguards for many processes where oil or gas fired burners are used has been developed by Minneapolis-Honeywell Regulator Company.

The device, known as the new Protectoglo, operates on flame rectification principles. It makes use of the fact that either a flame, or a photocell sighted at a flame, is capable of not only conducting an electric current, but of rectifying an alternating current.

The Protectoglo system can be interlocked with any needed combination of control devices and accessory equipment, such as excess-pressure, low-pressure and low-water safety cut-off, temperature control, alarms, signal light, etc. It can be used for single or multiple burner installations.

For further information circle No. 355 on literature request card on p. 668A

356. Alloy Handbook
New pocket-size Alloy Handbook. It's a mine of nonferrous alloy information — and it's yours for the asking. *Riverside Metal Co.*

357. Alloy Tubing
New catalog contains complete list of products and prices in warehouse stock of alloy steel tubing. *Timken Roller Bearing Co.*

358. Alloys
Technical bulletin, "Cast 16% Cr – 35% Ni Alloys", completely illustrates heat, corrosion and abrasion-resistant cast alloys. *Electro Alloys Div.*

359. Alloys
Hastelloy nickel-base alloys are available for fabricating corrosion-resistant screen, cloth and baskets. Also for metal spraying many types of automatic welding and hard-facing. Booklet, "Hastelloy High-Strength Nickel-Base Corrosion-Resistant Alloys", gives full details. *Haynes Stellite Co.*

360. Alloys, Copper
Bulletin, "How to Buy High Quality Copper Alloys", discusses the importance for the purchaser to accompany his specifications with full particulars on forming and fabricating methods to be used. Includes sample check list and requisition form especially designed for ordering copper-base alloys. *Riverside Metal Co.*

361. Alloys, Fabricated
New catalog is available, showing cost-cutting fabricated heat treating equipment for higher pay loads and better quality. *Rolock, Inc.*

362. Aluminum
Copy of "Alcoa Aluminum Impact Extrusions" will be sent on letterhead request, giving full information on impact extrusion process and service. Shows whole range of shapes for engineering. *Aluminum Co. of America.*

363. Belts, Metal
Bulletin 47P illustrates and describes complete line of wire belts for industry. *Ashworth Brothers, Inc.*

364. Bimetal Elements
64-page catalog written especially to help the design and product engineer select the type and size of thermostatic bimetal element best suited to his temperature-responsive device. *W. M. Chace Co.*

365. Blackening Process
New bulletin illustrating and describing the Ebonol blackening process for steel, copper, brass, zinc parts. *Enthone, Inc.*

366. Blast Cleaning
There is a Pangborn rotoblast table, barrel, or table-room designed to bring you amazing savings. Write for bulletin 214. *Pangborn Corp.*

367. Castings
Very attractive, well illustrated booklet on "Modern Metallurgy for the Industrial User of Iron and Steel Castings". *Hunt-Spiller Mfg. Corp.*

368. Castings
Two booklets: One, entitled "Engineering Properties and Applications of Ni-Resist", includes corrosion data on Ni-Resist and cast iron under 400 different corrosive conditions. The other, "Buyers' Guide for Ni-Resist Castings", lists producers of these superior castings. *International Nickel Co.*

369. Castings
Bulletin FC-350 outlines the many advantages of improved Fahrite corrosion-resistant castings. *Ohio Steel Foundry Co.*

370. Castings, Alloy
New 1950 Reference Chart contains comprehensive analysis of stainless, corrosion and heat-resistant alloy castings. Gives Copper alloy type numbers, along with comparative designations of AISI, SAE, ASTM, etc. In addition, lists properties of alloys at room temperature and high temperatures and discusses their applications. *Cooper Alloy Foundry Co.*

371. Castings, Precision
4-page leaflet discusses metallurgical and ordering service available to help in ordering investment castings. *Engineered Precision Casting Co.*

372. Cast Irons
"Production of Nodular Cast Irons with Cerium" gives details of actual practice in adding cerium to the foundry melt as developed by the British Cast Iron Research Association. First release in America. *Cerium Metals Corp.*

373. Cerium Metal
New bulletin describes how GCC Mischmetal added in small quantities to many ferrous and nonferrous metals improves metallurgical and mechanical properties of end products. *General Cerium Co.*

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

374. Combustion Control
"Combustion Control for Industry", a new fact-filled free booklet now available, shows how greater savings can be realized by proper combustion in heat treating units of any size. *Cities Service Oil Co.*

375. Copper Sheets
New 23-page booklet, the product of a ten-year program of design developments and tests combined with field investigations, contains complete, detailed specifications for all types of sheet metal installations employing copper. *Revere Copper & Brass, Inc.*

376. Electroplating
Circular 1173 illustrates the Cenco Electroanalyzer for qualitative measurement of the electrode deposition of metals. *Central Scientific Co.*

377. Fasteners
Complete file folder contains illustrations and engineering descriptions of fasteners and fittings for resistance welding, adjusting screws, adjustable feet and other products. *Ohio Nut & Bolt Co.*

378. Free-Machining Bar Steel
Reprint of article entitled "La-Led, a New Free-Machining Bar Steel", by Glenn D. Bayer, metallurgist at LaSalle Steel, discusses the advantages and characteristics of the new steel. *LaSalle Steel Co.*

379. Furnace
New brochure describes batch-type controlled atmosphere furnace in actual plant operation, including charts showing uniformity of gas-cyanided case depths obtained and typical operating cost breakdowns for light case parts. *Dow Furnace Co.*

380. Furnaces
New all-purpose furnace described in bulletin HD-646 may be used for carburizing, nitriding, dry cyaniding, bright annealing and clean hardening. *Hevi Duty Electric Co.*

381. Furnaces
Catalog A-17 illustrates and describes the line of Sentry electric furnaces for high quality hardening to produce maximum toughness and exceptional durability in high speed steel and high carbon, high chrome. *Sentry Co.*

382. Furnaces
Bulletin 424R lists many advantages of Rockwell retort furnaces for continuous automatic heat with accurate control of heat rate and product uniformity. *W. S. Rockwell Co.*

383. Furnaces
New combustion system and furnace design provide fast, high-temperature heating for production forging. Fully described in bulletin SC-144. *Surface Combustion Corp.*

384. Furnaces
72-page bulletin 116 describes electric salt bath furnaces and their many uses in hardening, annealing, brazing, tempering, quenching, etc. *Ajax Electrothermic Corp.*

385. Furnaces, Atmosphere
Fully descriptive literature available on versatile, controlled atmosphere furnace for all steels from high carbon to high speed in range 1200-2000 F. *Delaware Tool Steel Corp.*

386. Galvanite Handbook
A new 12-page, illustrated handbook explaining the uses, manufacture, and advantages of Galvanite, a special hot-dip, zinc-coated steel produced by this company. *Sharon Steel Corp.*

387. Gas Generator
Bulletin 1-11 describes how new inert gas generator Model 1 M1HR, rated at 1000 c.f.h., obtains the same analysis of inert gas regardless of demand. Fully automatic, it gives accurate proportioning and assures precise analysis over full operating range. Ratio control adjusts for manufactured, natural, propane, butane or refinery gases. *C. M. Kemp Mfg. Co.*

388. Hardness Testers
Bulletin DH-114 contains full information on Tukon hardness testers for use in research and industrial testing of metallic and nonmetallic materials. Also included is bulletin DH-7, giving experiences in various fields. *Wilson Mechanical Instrument Co.*

389. Heat Treating
Bulletin 123 describes how production is doubled, surface protection improved, and life of tools increased through the use of Ajax salt bath heat treating equipment. *Ajax Electric Co.*

390. Heat Treating
Folder describes new improved Pentrate process for rapid, durable, economical black finishing for steel. *Heatbath Corp.*

391. Heat Treating
Pressed steel lightweight sheet alloy heat treating units furnished in any size, design or specification. Write for full information on this. *The Pressed Steel Co.*

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

392. Induction Heating

More economical production made possible through redesign of heat treating methods. Full details on application to individual plants furnished in booklet "A Tocco Plant Survey — Your Profit Possibility for 1950". *Ohio Crankshaft Co.*

393. Lubrication of Hot Metals

New bulletin 426 describes how (DAG) colloidal graphite can solve your lubrication problems in hot metal forming operations. *Acheson Colloids Corp.*

394. Machine Design

Fundamentals of producing low-cost machine parts — design, material and treatment — are discussed in new 72-page "Three Keys to Satisfaction". *Climax Molybdenum Co.*

395. Mercury Cathode

Bulletin 220-1 describes completely new magnetic mercury cathode Dyna-Cath and shows how it permits economical use of established procedures for high speed separation of iron in determination of aluminum in steel. *Eberbach & Son Co.*

396. Metal Cutting

New 64-page catalog gives prices and describes complete line of rotary files, burs, metalworking saws and other products. *Martindale Electric Co.*

397. Microcastings

This 16-page booklet describes many applications for microcasting and also explains the process itself. *Microcast Div., Austenal Laboratories.*

398. Oil Burner

New 24-page catalog 410 describes the Hauck proportioning oil burner. A precision instrument for better combustion, more accurate control of furnace temperatures and atmosphere. *Hauck Mfg. Co.*

399. Oil Quenching

Catalog V-1146 gives detailed information on self-contained oil coolers, together with easy selection tables. *Bell & Gossett.*

400. Oven, Wide Range

Information is available on this new wide-range oven — 300° to 2400° F. — all-in-one furnace. *Sunbeam Stewart Industrial Furnace Div.*

401. Polishing

New booklet, "Polishing Cloth and Abrasives", furnishes first-hand description and classification of some of the most used but least described accessories in modern sample preparation. *Buehler, Ltd.*

402. Polishing

New booklet on the Electro Polisher gives latest information on this highly improved polishing machine for the metallurgical laboratory. *Buehler, Ltd.*

403. Pressure Vessel Accessories

Valuable reference catalog 9-49 contains 60 pages of important information on pressure vessels, styles and types and other handbook material. Sent upon request on company letterhead. *Lenape Hydraulic Pressing & Forging Co.*

404. Pyrometer

Catalog 1101-J describes how the new multiple-point Celectray controls up to six furnaces with the accuracy of a single-point instrument. *Weston Instrument Co.*

405. Pyrometer

Catalog No. 80 illustrates and describes the Pyro Optical Pyrometer for quick, accurate temperature readings on minute spots, fast moving objects and small streams in a temperature range from 1400° F. to 7500° F. *The Pyrometer Instrument Co.*

406. Quenching

"Handbook on Quenching" contains 60 pages of helpful data on the why and how of quenching. *E. F. Houghton & Co.*

407. Refractories

Complete details on refractory cements for every nonferrous melting operation are available in catalog 863. *Norton Co.*

408. Refractories

New Insulation Chart IN-6D gives recommended insulation for every temperature range from minus 400° F. to plus 3000° F. *Johns-Manville Corp.*

409. Sawing

Bulletin 2-MP illustrates the circular sawing of metals, and new automatic triple-chip method for sawing stock up to 6 in. accurately without burrs. Write for details on company letterhead. *Motch & Merryweather Co.*

410. Saws

Catalog 49 describes complete line of metal-cutting saws, covering 35 models in 10 basic types, and including the world's fastest automatic production saw, the largest hydraulic hack saws, and some of the most widely used small shop saws. *Armstrong-Blum Mfg. Co.*

411. Solders

Bulletin 45 gives full information on low-temperature silver solders. Samples sent on request. *American Platinum Works.*

412. Steel, Alloy

New 24-page booklet, "How to Specify and Buy Alloy Steel with Confidence", emphasizes the importance of careful selection, positive knowledge of properties and accurate heat treatment in purchasing alloy steels. *Jos. T. Ryerson & Son, Inc.*

413. Steels, Alloy

New book is now available on the selection of the proper alloy steel grades for each manufacturer's needs. Write for free copy of "Wheelock, Lovejoy Data Book". *Wheelock, Lovejoy & Co.*

414. Steels, Alloy

"Heat Treating Republic Alloy Steels", a 36-page illustrated booklet, provides an explanation of various heat-treating methods now generally used, and includes charts showing the mechanical properties obtainable in response to tempering at various temperature levels for 21 types of constructional alloy steels. Write for Adv. 340. *Republic Steel Corp.*

415. Steels, Low Alloy

You can have one-third more production through the use of Hi-Steel, which has nearly twice the working strength of ordinary steels plus the ability to stand up under impact loads. Send for free booklet. *Inland Steel Co.*

416. Steels, Spring

New catalog illustrates and describes a line of 785 different sizes of cold-rolled strip steels, with complete information on each size. Also contains useful reference tables for weights of strip steels, with comparative tables of wire gauges, numerical hardness, and temperature conversion tables. *Sandvik Steel, Inc.*

417. Steels, Stainless

Weekly lists with analyses of all plates in stock will keep you regularly informed on latest data. *G. O. Carlson.*

418. Steel Selector

Handy, clearly printed, easy-to-use tool steel selector, illustrated on page 562, will be furnished on request. *Crucible Steel Co. of America.*

419. Stress-Relieving

New 4-page catalog folder describes how many unnecessary cleaning operations can be eliminated by new, practical, Steam Homo method for stress-relieving of small brass parts. *Leeds & Northrup Co.*

420. Testing

Simple, accurate, 34-inch-high machine provides speedy testing of tensile strengths up to 20,000 pounds. Literature available. *Detroit Testing Machine Co.*

421. Testing

No. 39 is a new special bulletin on ductility testing machines for forming sheet metal. *Tinius Olsen Testing Machine Co.*

422. Testing Equipment

Bulletin 261-A contains a long list of supplementary devices for adapting basic machines to widest possible variety of testing situations. *Baldwin Locomotive Works.*

423. Toolsteels

Countless advantages of using J & L "E" steels for better tool production described in booklet, "Faster Machining, Smoother Finish, Longer Tool Life". *Jones & Laughlin Steel Corp.*

424. Trays and Baskets

Bulletin 501 illustrates and describes the heat and corrosion-resistant products manufactured for special heat treating jobs. *Alloy Engineering Co.*

425. Tubing

New booklet, "Fabricating and Forging Steel Tubing", tells how to slash production costs and increase style and practicability of your products with Ostuco tubing. *Ohio Seamless Tube Co.*

426. Turbines

Bulletins available as follows: Data book 107, Gas Boosters 109, Four-Bearing 110, Blast Gates 122, Foundry 112. Descriptive bulletin 127 and Technical bulletin 126. Send for each by number for particular application. *Spencer Turbine Co.*

427. Vacuum Metallurgy

Bulletin entitled "National Research Corp. and Vacuum Metallurgy" gives brief resume of the vacuum metallurgical operations and background of this company and of the research and development facilities and services available to the metallurgist. *National Research Corp.*

428. Zinc, Coatings

16-page illustrated booklet discusses the origin of galvanizing, the various zinc coating methods employed today and the advantages of zinc as a protective coating for iron and steel products. *St. Joseph Lead Co.*

[• If mailed from countries outside the United States, proper amount of postage stamps must be affixed for returning card]

METAL PROGRESS

7301 Euclid Avenue, Cleveland 3, Ohio

May, 1950

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Please have literature circled at the left sent to me.

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Postcard must be mailed prior to August 1, 1950—
Students should write direct to manufacturers.


In Wet Weather—
In Dry Weather


EVEREADY

Melting and Casting of Nickel Silver

(Starts on p. 650)

water-cooled molds through a runner box. The pouring stream must be kept short, smooth, and slow running, so that no breaking of the oxide film occurs. In this particular case a flaming dressing is used and a fine crystal structure is obtained, suitable for hot rolling. Temperature control is important, 50° F. being a reasonable limit for ingots for hot rolling. A wider limit is permissible for smaller shapes. After the first metal has entered the mold a slight oscillation is given to the ladle to avoid local hot spots. Casting temperatures are given for brass strip ingots with copper content between 63 and 80% for both chill iron and water-cooled molds:

	Chill Iron Molds	Water-Cooled Molds
80% Cu	2150° F.	2100° F.
70	2050	1975
67	1975	1850
63	1940	1885

In reply to questions raised during the discussion, the authors emphasize the benefit of iron addition to a 60-40 brass for hot working purposes, as an offset to increasing amounts of lead. A method is described for shutting down a low-frequency furnace. The grain refinement effect of flaming dressings is ascribed to the turbulence produced, while the large grain size obtained with the nonflaming type may be attributable in part to the insulating effect of the dressing.

Sixth and last paper of the symposium was "The Melting and Casting of Nickel Silver at the Works of Messrs. Henry Wiggin and Co., Ltd.", by E. J. Bradbury and P. G. Turner (18 pages, 4 plates, no references). The paper deals with the company's operations since 1929. Methods of meeting the unusual demands of the war are described. Among the final products for which the wrought forms are used are spoons, forks, hollow ware, telephone contact springs, decorative architectural work and as a basis for silver plate. The melting processes for all nickel silvers are practically identical, the only variations being in casting temperature and ingot shape.

In general the methods used would be considered out-of-date by American operators. For instance, electric furnaces are not employed,

(Continued on p. 672)

...to increase production per unit and per man"

"It must happen in a lot of shops. When a variety of metal working and metal cutting operations are involved, it's easy for the lubrication guides and the metal cutting requirements to get out of date. In our case, the outmoded requirements resulted in serious curtailment of per unit and per man production.

"We experimented quite a lot on our own but finally called in a Cities Service Lubrication Engineer. In an amazingly short time he diagnosed our trouble. Then he set up an air tight schedule. It was easy to follow. It cost no more and the production results were immediate. This man knew his business. Our new production figures are definitely something to brag about."

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Melting and Casting of Nickel Silver

(Starts on p. 650)

and no pyrometers are used to take the temperature of the metal as poured.

A cost figure for a 50-lb. water-cooled mold indicates how the prices for such equipment have risen in England in ten years. In 1936 the cost was £65 and in 1947 for the same mold, £230.

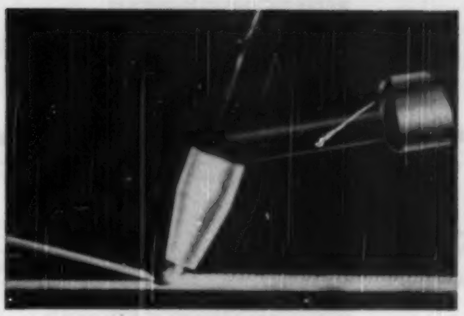
Despite the large percentage of zinc in the alloys it was found advantageous to "deoxidize" the melt before casting. To do this 1 oz. of manganese and ½ oz. of phosphor copper was added to each 50 lb. of nickel silver. The phosphor copper prevented cracking of the sheet and strip for spinning and pressing applications.

In the discussion it was stated that carbon is picked up more readily from silicon carbide crucibles than from graphite. The question was asked: Why was the zinc charged at the same time as the other metals? It was stated that this practice does not lead to increased loss of zinc and that the authors believe that the practice inhibits the tendency of the virgin nickel to pick up carbon in the early stages of melting. It also gives quicker melting, owing to faster alloying. The manganese addition checks any tendency toward graphite formation and also keeps down the sulphur content. Phosphor copper prevents "fire-cracking" by enclosing the lead globules in an envelope of phosphor copper, which remains intact up to about 1650° F. and so prevents intergranular penetration of lead.

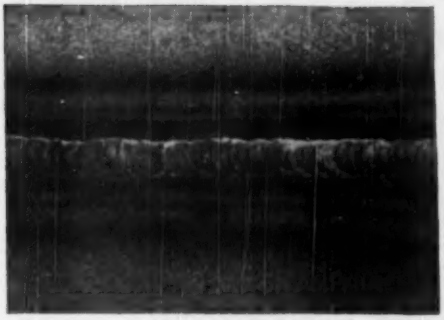
Soro Process — In the general discussion, Dr. R. Genders referred to the Soro process used on the Continent. This consists in casting centrifugally a ring of nonferrous metal such as bearing bronze, 39 in. in diameter, having the section of the bar that it is desired to make. The molten alloy is poured down a spout leading into a revolving ring-shaped divided mold. The cast ring, resembling a thick hoop, is extracted when the mold is parted. The ring is then cut and straightened out to form a bar 10 ft. long. Being cast centrifugally the structure is very fine and free from slag and nonmetallic inclusions. It is either drawn and used for machining or cut into lengths for forging. The original plant is understood to be producing 1000 tons a year.

Weld Sheet Steel with the HELIARC torch

Trade-Mark



and wipe out one complete operation



AS WELDED — *This photograph, unretouched and natural size, shows that* HELIARC *welds in sheet steel are clean and uniform.*

There is no spatter or flux, so you save cleaning costs when you switch to the HELIARC process for welding sheet steel. And you keep the advantages of high speed, and minimum distortion that are characteristic of arc welding. Any manual arc or gas welding operator finds welding with a HELIARC torch easy to master.

Porosity-free welds in killed low-carbon steel up to ⅛ in. thick can be made with this process. In non-killed grades, welds are as nearly gas free as can be produced by any welding process. Argon-shielding prevents pick-up of atmospheric gases. No argon is dissolved in the weld.

Joints welded with the HELIARC torch will not show under paint, lacquer, or even vitreous enamel finish. It takes only a light grinding to remove the low, smooth ripple and make the bead flush with the surface.

Get more information on this fast, clean, welding process from any LINDE office. Let us show you how it can improve your product and cut your costs. Just fill in the coupon.

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Gentlemen: We would like more information on welding sheet steel with the HELIARC torch. We manufacture ....
(Product)

from .... of ....
(Metal) (Thickness)

We are ☐ (are not ☐) now using inert gas-shielded welding

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Company...

City............................ ....State...........

Oxidation of Mo

(Starts on p. 629)

shown in Fig. 2 would have to be substantiated by experiments at more closely spaced temperature intervals.

In relation to the problem of increasing the oxidation resistance of molybdenum by alloying, the above results indicate that such resistance would be attainable only by replacing the porous, fusible, highly volatile oxide (MoO_3) formed on heating pure molybdenum by a refractory, nonvolatile, and more compact oxide scale. This might be secured by replacing MoO_3 entirely by one consisting of, for example, Cr_2O_3, Al_2O_3, SiO_2, BeO, or MgO, formed by oxidizing the alloy of molybdenum with the respective metal. In general, however, it is necessary that such alloying elements be retained in solid solution in the original or basis metal in order to exert an appreciable protective effect, and further that fairly large amounts of such elements be present — on the order of 5 to 25%. Since molybdenum has only a slight solubility for most of the metals which form refractory oxides, it is probable that satisfactory results can be obtained only by the use of a number of these metals in combination.

Correspondence

CAMBRIDGE, MASS.

This unusual flower, tentatively termed *narcissus oxidoxa*, was grown in one day from a seed (16 Cr–25 Ni–6 Mo alloy) in a suitable environment (air at 1900° F.) at M.I.T. Petals are spinel type.

ANTON DESALES BRASUNAS
Department of Metallurgy
Massachusetts Inst. of Technology

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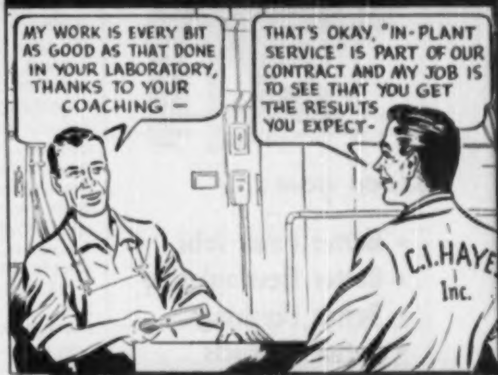
Because we were pioneer designers and builders of controlled-atmosphere electric furnaces, our service men have had an unparalleled opportunity to gain experience in adapting our equipment to solving customers' problems. When you call on Carl Paulson, Dick Elliott, Bill Diman, Mo Jones, for service, you are tapping an absolutely unique service of controlled-atmosphere heat treating experience, backed by laboratory facilities and engineering know-how representing the longest experience in the business.

Truly, C. I. Hayes Inc. offers you, in this combination of product and service, "Insured" Heat Treating! Why not buy the best first?

CARL G. PAULSON,
Service Manager

IN YOUR PLANT



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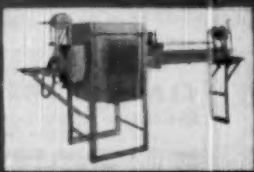
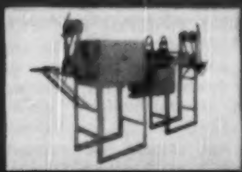
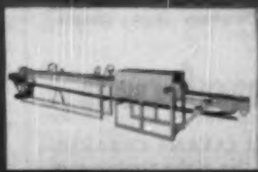


ANNEALING STAINLESS — SINTERING



COPPER BRAZING & SOLDERING



CONVEYOR ANNEALING

LEAD POT

Swedish Toolsteels

(Starts on p. 643)

being. Consumers suggested that some sort of hardenability test should be included in the standard specification. It was argued that especially for carbon steel the composition specification alone might not be sufficient to insure uniform results in heat treating. An indication of hardness penetration *was* given for the three carbon steels standardized, but this was not made compulsory, especially as no simple and decisive hardenability test could be agreed on for carbon steel.

In some cases two steels with similar properties and intended for the same purpose have been standardized. Thus steels 2092 and 2140 are both oil hardening, low-alloy, "nonshrinking" steels. They are so extensively used in Sweden that the adoption of both as standard grades seemed justified. Steel 2092 is sometimes preferred where especially good wearing qualities and keenness of edge are desired, but it is somewhat less easily machined than steel 2140 in the annealed condition.

Similarly the two steels 2310 and 2312 are similar high-alloy types. For certain purposes where toughness is especially desired, steel 2310 has proved superior, but 2312 is the most widely used.

Steel 2260, of a type fairly widely used in the United States, is now becoming increasingly adopted in Sweden. It is intermediate as regards properties, costs and uses between the low and high-alloy types mentioned above.

Steels 2700 and 2705 both have rather varied applications. Steel 2700 is much used on the home market, but steel 2705 with its greater hardenability is a more international type and it seemed necessary to standardize both steels.

It was pointed out from several quarters that the Swedish workshops ought to be able to get along with fewer than four high speed steels, but all four types now standardized are regularly used.

It should be emphasized that the specifications are not to be considered irrevocably settled for all future time, but must be successively modified according to technical developments. The standardization does not prevent Swedish industry from producing, selling, testing and using nonstandardized grades of toolsteel and the standardization will not impair the competition necessary to stimulate development of new and better grades.

The HOUGHTON LINE NEWS

VOL. 18, NO. 2 MAY, 1950

...the "near editor's" viewpoint...

Many folks who ask for advice really only seek approval.

The main difference between the atom bomb and the H-bomb is that the latter will kill a lot more people. The "civilized" world has gone insane on bombs. They may have helped win the last war, but they never settled any of the issues, and may even cause another war. We hope the much publicized H-bomb will be a complete dud!

Secret of "creosote" flavor of Scotch is revealed in the April "LINE." And one reader tells us that "it is common knowledge that Scots expectorate and shut their eyes before drinking theirs straight, to avoid diluting it with any moisture or from crying into it when they think of the price."

Aaron E. Carpenter
CHAIRMAN OF THE BOARD.

Annealing Precious Metals

A new salt bath, which eliminates "fire" (oxidation) deposits on silver, gold, copper or brass being annealed, was described in the January "LINE." If you have such a problem, ask about *Liquid Heat 1185.*

Sleeves in Salt

Cylinder sleeves and piston rings are isothermally heat treated in salt by a Cleveland manufacturer, at a saving reported to be as high as 15% over other methods. The mechanized series of salt baths includes a preheat in our *Liquid Heat 950,* high heat (1550° F.) in Liquid Heat 168, and quench in Mar-Temp Salt at 450-500° F. It's a faster, surer, modern method of heat treating which avoids distortion. Entire cycle is described in a recent "LINE" article, available on request.

By the mere change of cutting fluid used for machining the above clamp, all this was accomplished: brighter screws, 15% greater production, 50% longer tool life. The coolant: Antisep All-Purpose Base, mixed 1:25 with water. Costs less, too!

7¢ A PART SAVED!

Hot Oil Quench Enables Finish Grind Before Heat Treating

Evidence piles up that there are many cost-cutting possibilities in the use of Houghton's MAR-TEMP Oil. Witness this experience of an automotive manufacturer:

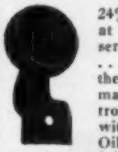
There was heat treating trouble with a forging used as a control sleeve for a free wheeling mechanism. The treatment was changed to a cyanide bath at 1550° F., followed by a Mar-Temp Oil quench at 300° F. Dimensions hold accurately! This enables parts to be finish ground before heat treatment. And, the saving is 7¢ a part!

Martempering is today an accepted form of quenching to avoid distortion and cracking. It has proved a real boon to firms who had trouble holding parts within close dimensional tolerances. Before development of a stable hot oil, molten salt was the only martempering medium, being used at temperatures above 400° F. Houghton supplies a special salt for this purpose.

But, for the many firms who need a hot quench but do not have enough work to warrant special furnace set-ups, or who do not require the higher temperature quench, we developed this special oil. It is stable and long-lived at temperatures up to 350° F. Like the manufacturer cited above, many users have found it economical and entirely satisfactory for long periods of time.

Others may be able to effect these same economies; write for complete data.

How to Lubricate Hot Spots



24% of the time in an oven at 500° F. . . . never out of service for over two years . . . still running free. That's the report from a porcelain manufacturer on a conveyor trolley regularly lubricated with Houghton's *Hi-Temp* Oil No. 227. Hi-Temp Oils warrant a trial for any "hot-spot" lubrication problem of yours. Information on them is quickly available.

Cleaning Problem Solved

A cleaner is good when it will remove a thick, tarry coating from nuts and bolts. So concluded a manufacturer who bought a carload of dirty parts from government surplus. The tar wouldn't come off in an alkaline bath. Nor did a steam blast help. But the job was done with HOUGHTO-CLEAN 220, our emulsion-type cleaner. And, *perfectly!* Write for Data Sheet and prices.

Costs Tumble

Cleaning of metal parts in tumbling barrels, formerly done with alkaline cleaners, is now being done by a Houghton customer, at much lower cost, using our *Cerfak* synthetic detergent. Two gallons of this non-ionic detergent are mixed with 50 gallons of water to make up a stock solution. Each tumbling barrel requires about one quart of this solution plus a pound of TSP. Work is tumbled 5 minutes then rinsed in the barrel. Result: Clean parts at a cost of 9 cents as compared to 42.5 cents by former method. Metal plants cannot afford to overlook possibilities of synthetic detergents for cleaning.

Safeguards Against Rust

Out of Houghton's Research Laboratories—a real proving ground for metal working supplies—has come a new series of rust preventives. Eleven proven safeguards are described in a new bulletin titled "An All-Star Series." Let us know if you want a copy.

If you hunt or fish, we have a free half-pint sample of Cosmoline FR for you. It is an approved lubricant and rust preventive for fishing reels and guns. Ask for it on your business letterhead—Dept. MP. And while you're about it, tell us which of the following is—

1. HYDRO-DRIVE HYDRAULIC OILS—Listing the physical requirements of oils used for hydraulic purposes, and demonstrating the advantages of improved resistance to high pressures, heat, moisture and agitation.
2. LIQUID CARBURIZERS—description and working ranges of PERLITON carburizing salts.
3. DRAWING COMPOUNDS BY HOUGHTON—a folder that can put you on the road to saving money on drawing operations.
4. "HOT SPOT" LUBRICATION—All about HI-TEMP Oils, mould lubricants, etc.
5. HOUGHTO-SOLV—Fuel Oil additive that takes sludge into solution, makes messy, costly tank cleaning unnecessary. 6-page folder.

E. F. HOUGHTON & CO.
303 W. LEHIGH AVE.
PHILADELPHIA 33, PA.

Tumbling for Low-Cost Finishing

(Starts on p. 625)

Wet tumbling may be divided into the following categories:

1. Coarse cutting, deburring or grinding with a medium to remove heavy burrs and excess metal on rough sand castings.
2. Normal cutting or polishing: a starting process for poor stampings and semismooth castings, or where surface conditions are such that they do not require coarse cutting. Using a medium, it removes light burrs, sharp edges and corners, and surface irregularities.
3. Cleaning: washing with the medium and a compound to remove residual abrasives.
4. Ball burnishing or coloring, using steel balls or shapes and compound for surface refinement to obtain a high luster.

For simple deburring where appearance is secondary, the wet process is likely to be more economical because coarser abrasives can be used, with faster cutting action. The disadvantage, however, is the coarser surface resulting and the darkening of the metal, which presents a less favorable appearance than work finished by dry tumbling.

Combinations of wet and dry operations may be effective in decreasing the time cycle. On certain classes of work a mixed cycle may include wet grinding with dry cutting down, followed by either dry or wet burnishing for final finish. Wet burnishing is normally used after wet or dry polishing to produce the highest luster. Combination processes are usually determined by the equipment available and the time cycle called for.

For maximum output, the highest speed possible without injury to parts should be used. Small tumblers can be operated at higher speeds than large, without danger to the parts. Dry tumbling must be slower than wet, in order to minimize the harder impacts that are caused by the absence of cushioning liquid.

Exact barrel speeds can be set only by experience and trial. For barrels 18 in. and larger in diameter, peripheral speeds of 100 to 200 ft. per min. have been recommended. Large parts call for low speeds; small parts, higher speeds. About 35 r.p.m. is average for small substantial pieces, while parts that can stand a heavy throw will take speeds ranging from 40 to 70 r.p.m. Large or fragile parts are limited to 30 r.p.m. or less. Substantially

(Continued on p. 682)

Tumble Finishing

(Starts on p. 625)

higher speeds can be used if the parts are racked inside the barrel instead of being tumbled loose.

Oblique barrels run at from 6 to 40 r.p.m., the larger barrels running slowly and the smaller barrels faster. The average speed is 12 to 20 r.p.m.

Barrel speeds are so critical that some operators feel it wise not to use a variable-speed control because workmen are likely to change the speed to suit their own convenience or ideas. Adjustable speeds obtained by interchanging motor pulleys are recommended as inexpensive and foolproof, especially where there are long runs of similar pieces.

Nicking, rough surfaces and other marring effects on the work can be reduced or eliminated by:

1. Decreasing the speed of rotation.
2. Decreasing the ratio of parts to medium or carrier.
3. Increasing the height of the load past the center of the barrel, thereby reducing the length of slide and force of impingement at the bottom.
4. Decreasing the size of the medium.
5. Decreasing the speed of rotation at start, with increase after sharp corners have acquired a slight radius.
6. Increasing the volume of water to cushion load.
7. Increasing the volume of fine, mild abrasive in water up to load level to form a cushion and reduce direct contacts.
8. Increasing the care in loading; for instance, alternate layers of parts and medium, or center-loading.
9. Increasing the care in rinsing in the tumbler after all cushion and lubricant have been removed; for instance, by lower speeds.
10. Checking screen doors used for rinsing and also regular doors and covers which may have defects and thereby mar the work. Protruding edges or corners inside the barrel should be eliminated.
11. Unloading by slides, chutes, baffles, canvas funnels, or other devices that will eliminate sharp falls.

A typical sequence of operations is as follows:

1. Load mass and parts into the barrel.
2. Add the recommended amount of water and the specified compound.
3. Clamp the loading doors in position.
4. Start the cylinder rotating and allow parts to process for the requisite time.
5. Remove parts and mass from the machine.
6. Separate parts from chips by screening.

(Continued on p. 686)

MR. TMPR* says: *"Consistent, helpful product advertising like this prompts me to action!"*

*Typical Metal Progress Reader

• Every month for twenty years Surface Combustion has been giving facts to MR. TMPR (pronounced Temper). Down-to-earth, well illustrated pages like this one keep the 21,000 Metals Engineers who read Metal Progress well acquainted with Surface furnaces and industrial burners.

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• *Write us on your letterhead for a special report that gives the details of our most recent readership survey.*

Largest Engineering Circulation in the Metal Industry

Metal Progress

Basic in Metals Engineering

Tumble Finishing

(Starts on p. 625)

7. Dry parts and send to next operation.

Tumbling time is highly variable. Deburring time may be from 15 min. to 10 or 12 hr.; grinding time, from 8 to 48 hr.; polishing time, 15 min. to 16 hr.; burnishing, from a few minutes for gold plate to several hours for steel. The average time to deburr machined or stamped steel, brass or aluminum parts has been stated as from 1 to 4 hr.; to finish a zinc-base die casting preparatory to electroplating with copper, bright nickel and chromium, 6 to 8 hr.

After barrel tumbling, parts should be well rinsed and dried as rapidly as possible by tumbling in sawdust or corn cobs, by centrifugal drying, or by oven.

After each tumbling operation, the work must be rinsed well before proceeding to the next step, to remove the last traces of abrasive, compound and dirt. This is done by tumble flushing, filling the barrel with water, replacing the solid cover with a perforated cover and turning the barrel through a few revolutions while the water, compound and abrasive residues are discharged through the perforations. This operation should be repeated as many times as necessary.

Cleanliness is most important. Each barrel should be used for only one of the various operations, cutting down, smoothing or cleaning, polishing or burnishing. Despite the most thorough cleaning, some abrasive or compound may adhere to the lining, and it will contaminate the next operation where a different abrasive or compound is used.

Rack Tumbling

Very large pieces or parts with complicated shapes, seemingly unsuitable for tumbling, can be racked or fixed in place in the barrel so that the abrasive and carrier circulate about them. The racks may be removable and, therefore, loaded and unloaded outside the barrel; or they may be anchored in place and loaded in the barrel. The former is preferable. Barrel motion should be reversible to insure treatment of all surfaces, recessed and otherwise. The barrel is loaded completely around the periphery.

Racked work can be run at high

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speeds. Compound and carrier are loaded sufficiently to cover the parts when they are at the low point in the barrel.

Specific Examples

A specific example is a job on zinc-base die castings in which a system with two basic schedules is used, one for deburring and rough finishing, the other for burnishing. For deburring, the barrel is loaded with 750 lb. of clean limestone chips, 8 lb. of compound, and approximately 1 cu.ft. of load. The chips are of a size that will not lodge in the openings and with all rough surfaces smoothed. The compound is mildly alkaline and non-abrasive. The chips are first loaded into the barrel and thoroughly rinsed to remove any of the previous compound. The work load of die castings is dumped on top of the chips, after which the compound is added. If necessary, water is added and the barrel door clamped shut. After rotating for 5 hr., a rough finish is obtained. The door is then opened and the foam washed out with a water spray. The water is drained by rotating the barrel halfway and then the entire load is tipped out. The load is screened to separate the chips from the work, the rough finished parts water rinsed and dipped in a water-soluble oil.

If parts are to be burnished after deburring, they are left in the barrel with the chips after rough finishing. The original compound is thoroughly flushed out with water and then 8 lb. of another compound added. The barrel is sealed shut and rotated for an additional 2 hr., giving a finer finish.

The average load in this particular installation is approximately 2000 parts, deburred and rough finished in 5 hr. and completely burnished in 7 hr. A single operator handles six barrels simultaneously.

In another instance, working on small brass and bronze sand castings, efforts are first made to provide as good an as-cast finish as possible in sand molds and by subsequent blasting. Some castings may require grinding at partings to remove unusual rough spots, but this is not commonly required.

The first tumbling operation is done in unlined steel barrels about

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36 in. in diameter with conical ends, run about half full. The charge includes three volumes of castings to four of special egg-shaped die-cast zinc alloy slugs, about ⅞ in. long and ½ in. in diameter. To this charge is added 200 lb. No. 26 Albany sand containing about 15% clay and enough water to cover the charge. This operation takes from 24 to 40 hr., depending on the size, shape and initial condition of the castings. Barrel speed is from 18 to 26 r.p.m.

At completion, the charge is dumped, the sand washed out and the barrel flushed. The charge is then screened to separate castings from slugs and the castings are rolled in dry hardwood sawdust in steam heated, open, oblique barrels for 5 to 10 min. to dry.

After screening to remove sawdust, the castings are loaded into octagonal, wood-lined, one-compartment barrels, 24 in. in diameter, revolving at 26 r.p.m. The charge consists of 4 parts by volume of vegetable ivory chips, 1 part castings and 1 part hardwood sawdust, with about 8 oz. of medium-fine powdered silica. This operation is dry, continuing for 18 hr., at the end of which the scratches left by the sand in the prior wet tumble have been eliminated and the castings have a "bright scour". The charge is dumped and triple screened to separate the castings, the vegetable ivory chips and the sawdust.

The final tumble is dry, in wood-lined barrels revolving at 26 r.p.m. The mix consists of ¾ cu.ft. of castings, 3 cu.ft. of vegetable ivory chips, 2 cu.ft. of soft scrap leather clippings and 6 oz. of powdered nickel rouge. The castings emerge bright and ready for a wheel buff and color, a plate or an enamel finish.

Cast-iron parts do not suffer significant changes in tumbling but burrs and sharp edges are eliminated. The charge used is 1 volume of parts to 4 volumes of tumbling chips in 24-in. wood-lined barrels about half full, with the charge submerged in water. With the barrel operating at 26 r.p.m., the burrs are removed in about 10 min.

Bronze and steel parts are deburred in a similar mixture but the time required is longer, from 1½ hr. to as much as 8 hr. if burrs are heavy and tough. Nonferrous parts often require no other tumbling

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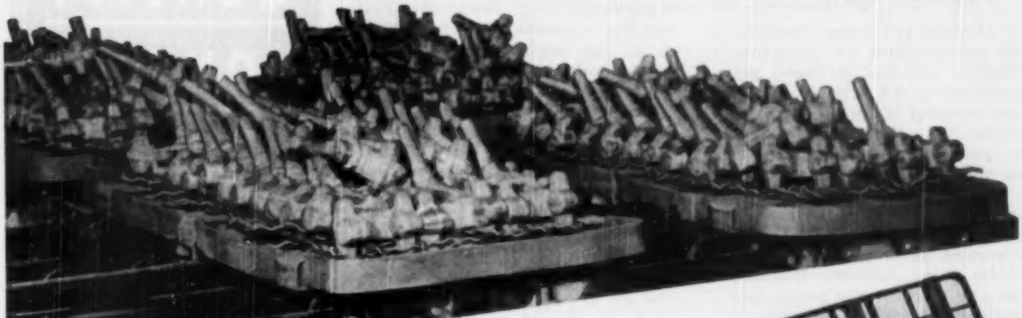

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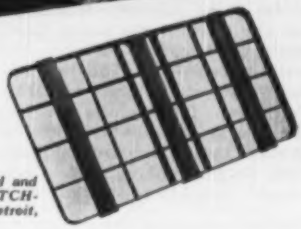

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Tumble Finishing

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after deburring, but steel parts are tumbled in twice their volume of hardwood sawdust in an open, heated barrel for 10 min. to dry quickly and retard rusting.

Applications and Limitations

As stated previously, tumbling is not recommended for completely finishing any and all metal parts. Tumbling is not suitable for complete shaping of parts or for major cutting jobs. All heavy flash should be previously ground off or removed with a trimming die.

Tumbling is, however, applicable to a much greater variety of work than is generally realized. The most important single factor is the shape of the parts, primarily because of the way in which the pieces "flow" during the tumbling operation. The best applications are those in which the weight of the parts is evenly distributed. Large pieces are less likely to be amenable to tumbling, although racking has brought much work into tumbling which was formerly considered impossible.

Some shapes are to be avoided: flat plain objects of large area; hollow shapes which require high interior finish; parts with deep-cored recesses; also, parts having one very heavy section which might cause them to fall always in the same position during tumbling.

The method of manufacture also helps to determine the number of steps required to achieve a suitable finish by tumbling. Deep tool marks, bad fins, accidental scars from handling, and similar markings may require uneconomically long tumbling cycles.

In general, it is most economical to tumble parts ranging from 1/16 to 4 in. in diameter; on these, tumble finishing can often show a saving of 50% over buffing. The greatest savings are obtainable by simultaneously deburring and polishing small pieces, especially those having irregular contours, such as are common in die castings. Among such parts are fishing tackle, watch, clock, jewelry and radio parts. However, large parts are also tumbled successfully, deburred and prepared for plating, such as windshield wiper parts, automobile parts (including door handles) and plumbing hardware. *(Continued on p. 694)*

Tumble Finishing

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Parts with male and female threads can be deburred. Sharp crests are rounded slightly in processing, but there is usually no measurable change in pitch. Similarly, gear teeth can be deburred with no change in the pitch and profile of the teeth.

One of the interesting advantages of the tumbling process for die castings which are intended for subsequent plating is that pores and microscopic holes beneath the surface are not exposed as they may be by wheel grinding.

Parts which, because of their complicated shapes, are difficult to polish on the wheel (such as a food-chopper worm) can be tumbled by a two-step operation, giving a good surface.

In a sense, the tumbling process is a challenge to the designer. Consideration given to this process in the design of component parts will result in faster and less costly finishing. Parts should be as free as possible from sharp corners, large flat surfaces and recessed areas. They should be shaped to permit the processing medium to reach all points equally well. Smooth radiused edges can be maintained within relatively narrow limits. Proper balance, the avoidance of any lopsidedness where one section of the part is much heavier or larger than its opposite is important. In addition, continuity of large surfaces should be broken up whenever possible by lines, fluting or some simple design pattern.

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